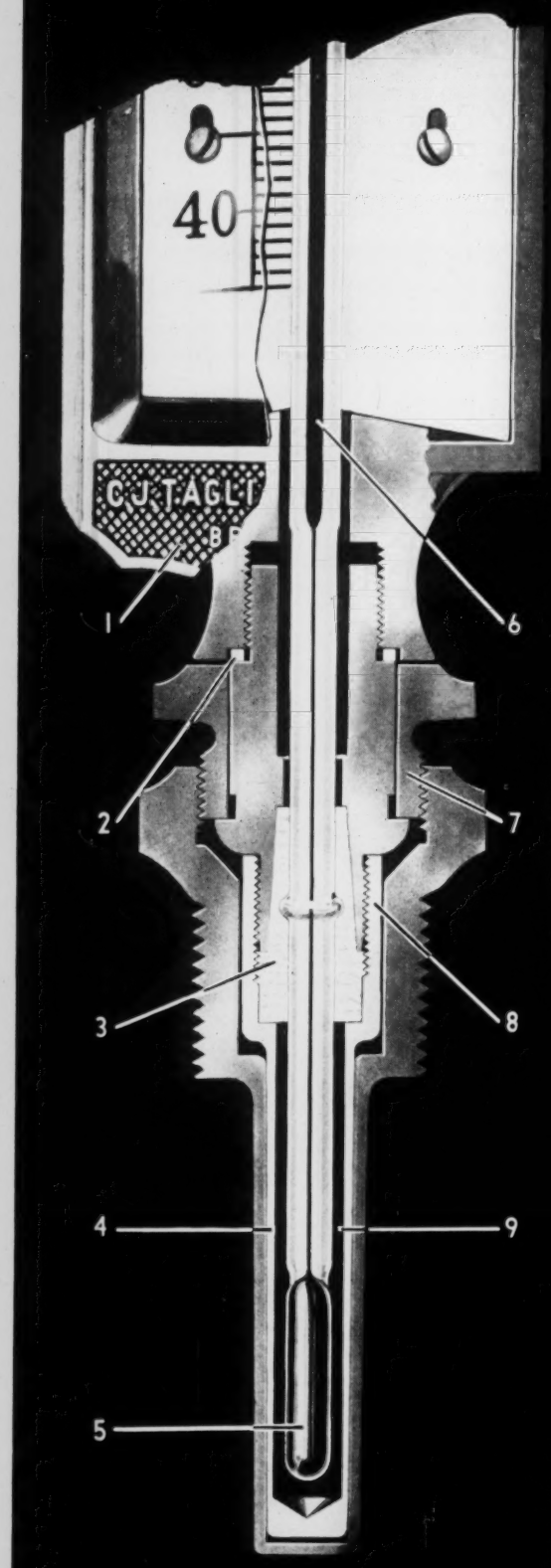
# Instruments

## THE MAGAZINE OF Measurement and Control

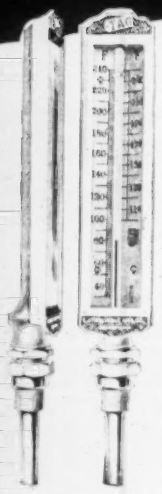
Vol. 12
SEPT.
1939
No. 9

**SCIENTIFIC CONSTRUCTION and DESIGN IMPROVEMENTS have made TAG THERMOMETERS the Natural Choice of American Industry!**




Section of TAG Separable Socket Thermometer 2½ Inch Stem, ¾ Inch s.p.t.

# TAG
## INDUSTRIAL THERMOMETERS



Over a million TAG THERMOMETERS have been bought by American Industry, which is ample evidence of the fact that they represent the highest state of perfection in design, construction and utility. Over the years, the traditional precision of TAG INDUSTRIAL THERMOMETERS has been steadfastly maintained . . . in step with modern practice, many new and desirable improvements have been made in these fine instruments.

## *Observe the many Outstanding Constructional Features*

1. The TAG Snap Case-Front makes cleaning easy. A tongue at the top of the case fits snugly in a groove in the front. It takes little effort to replace the front, which when on the instrument, is held firmly closed by the snap device. There are no screws to loosen, lose or misplace.
2. Connecting piece locked to case by a specially designed split spring washer.
3. Asbestos packing, uniformly compressed around enlargement of glass stem prevents movement of tube with reference to scale.
4. The stainless steel bulb chamber is thin enough to allow quick conductivity, yet rugged and non-corrosive . . . cannot amalgamate with the mercury filling.
5. The bulb is specially seasoned and aged to prevent molecular changes in use. It is thin, yet so uniform, that it will not crack with sudden temperature changes.
6. TAG Red-Reading Glass, with magnifying lens-front, is specially seasoned and guaranteed for permanent accuracy.
7. Coupling nut, revolving freely on stem of connecting piece for attaching Thermometer by means of a union or separable socket connection.
8. Left handed thread on bulb chamber prevents loosening if case is turned in removing Thermometer from socket.
9. Filling in bulb chamber completely surrounds bulb of Thermometer and insures quick transmission of heat.

Write us today for your FREE copy of the TAG INDUSTRIAL THERMOMETER Catalog No. 1125-I . . . 24 pages showing the complete line of these notable instruments. You will find it an asset to have on file.

TAG Industrial Thermometers are built for hard service, but glass tubes will break and metals will eventually corrode. TAG Industrial Thermometers can always be repaired, and a TAG Remodeled Thermometer carries the same accuracy, material and workmanship guarantee as a new instrument.

# C. J. TAGLIABUE MFG. CO.
**PARK & NOSTRAND AVES.,**
**BROOKLYN, N. Y.**

# Instruments

THE MAGAZINE OF *Measurement and Control*

M. F. Béhar, Editor



Vol. 12 No. 9

SEPTEMBER 1939



FRONT COVER: Instrument Room of Chicago Latrobe Twist Drill Works, Chicago
*Courtesy Leeds & Northrup Company*

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THE OUTBREAK of the war in Europe found Major Behar in the hospital and unable to take care of the September issue. The Managing Editor therefore had to take over and due to the vast amount of work required in putting an issue together, the editorial comment will be made especially brief.

The immediate effect of the war will be a quickened demand for all industrial products. To be sure the embargo will eliminate the demand for munitions to a considerable extent. However, even during the last war, the export of munitions was only about 10% of our total exports. American industries will be called upon to furnish many nations with products formerly furnished by the countries now no longer able to serve them. This demand for goods of all kinds will require gearing up to supply these needs. Measurement and control devices will be necessary to accomplish this gearing up.

After the last war, we can remember the gearing down of our productive mechanism to fractional levels of usefulness was so difficult, that many of our people never could get acclimated to their activities before the war.

Automatic machinery and automatic control devices will permit the necessary increase in production with the smallest subsequent displacement of labor.

Richard Rimbach

**DON'T FORGET THE INSTRUMENTATION CONTEST**

In the August issue appeared the announcement of the second Instrumentation Contest. A few days after the issue was mailed we received a letter from Dr. John Grebe, Physical Research Laboratory, Dow Chemical Company:

*"First of all let me congratulate you on the very comprehensive article on measurement and analyses of noise and vibration in the last issue of Instruments.*

*"Next, I am glad to notice that the subject matter of this year's contest is of the type that should interest all employees and employers. We will make an extra effort to get some papers from our group at Midland."*

**BE SURE TO MAIL IN YOUR ENTRY BEFORE NOVEMBER 15 AND SEND FOR YOUR ENTRY BLANK NOW.**

# MOELLER
## PRECISION GRADE INSTRUMENTS

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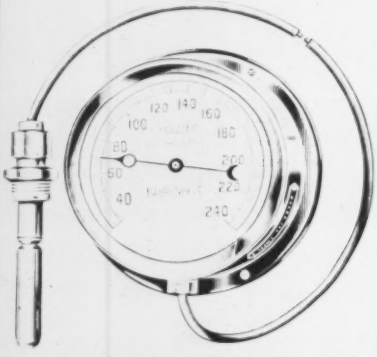
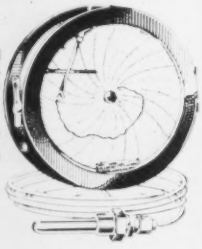
Our mercury thermometers are made with the Moeller Glass Red Reading Column which makes them easy to read under varying light conditions, at a considerable distance and over a wide range.

★



Moeller dial thermometers are made in various scale ranges up to 1000° F. or equivalent in both Metal and Phenolite cases.

Moeller recording thermometers are likewise furnished in various ranges up to 1000° F. or equivalent in both round and square cases.



*Other products include*

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BAROMETERS HYDROMETERS
MARINE INSTRUMENTS, ETC.

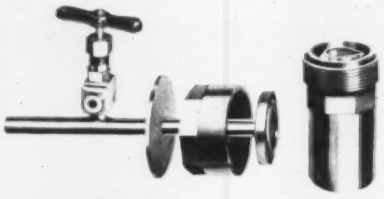
*Write for catalog.*

**MOELLER INSTRUMENT COMPANY**
132nd STREET and 89th AVENUE
RICHMOND HILL NEW YORK


# The MONTH'S NEW INSTRUMENTS

## Bomb for Determining Gum Stability of Gasoline

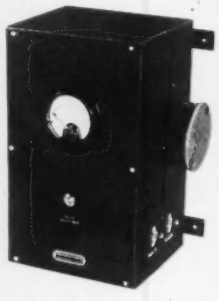
A bomb for determining gum stability of gasoline, used in connection with the latest A.S.T.M. method for gum stability of gasoline, D525-39T has been improved. This method describes the procedure for an ac-



celerated oxidation test of gasoline, by means of which the induction period is determined. The induction period may be used as an indication of gum stability, i.e. the tendency of gasoline to form gum during the period of storage. The method involves the use of a pressure gage, preferably of the recording type. The so-called "break" point of gasoline is defined in the method as that point provided by a pressure drop of exactly 2 lbs. in 15 min. and succeeded by a drop of not less than 2 lbs. in 15 min. The number of minutes from the time the bomb is placed in the bath held at a specified temperature to the "break" point is recorded as the induction period.—*C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

## Conductivity Apparatus for Distilled Water, etc.

New "Series DW" Automatic Distilled Water and Condensate Checker embodies refinements over previous model which, though lacking some of its features, is said to have been "operating satisfactorily for many years." It employs electrical conductivity principle as did previous model but



its control unit (illustrated) operates on 115-volt 50-60-cycle a.c. and includes a voltage regulator. Instructions and circuit diagrams accompanying equipment permit its installation to be made by plant electricians. In addition to cabinet and conductivity cell, there are available a 1" magnetic valve and an alarm bell.—*Industrial Instruments, Inc., 162 W. 23rd St., Bayonne, New Jersey.*

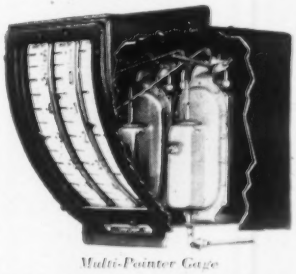

BAILEY METERS

# METERS and CONTROL for Boiler Room Service . . .

**Boiler Meters** Indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature. The use of this meter reduces fuel cost, lessens maintenance and outage, lowers standby costs, and adds capacity.

*Bailey Boiler Meter*

**Multi-Pointer Gages** for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



*Multi-Pointer Gage*

**Flow Meters.** For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

*Coal Meter*

**Granular Material Meters** For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

**Control Systems.** Make possible the every-day operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

*Complete Information on any of the above Bailey products will be gladly furnished upon request.*

**BAILEY METER COMPANY**
1041 Ivanhoe Rd., Cleveland, Ohio

★

## Moisture Teller

★

Rapid and accurate moisture test in percentage by drying. Drying temperature controlled by thermostat. Ideal for plant moisture control or laboratory moisture determinations.

Time required to dry most materials is one minute.

Suitable for granular—fibrous—crystalline materials is industries such as:

Sand—Textile—Tobacco
Ceramic—Rubber—Food
Wood—Mining—Leather

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**Harry W. Dietert Co.**

Dept. C—9330 Roselawn Avenue
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## Pointer-Stop Instruments

Pointer-stop ammeters are indicating instruments equipped with an adjustable stop, micrometer screw actuated, arranged to push the pointer upscale for measuring currents or voltages of short duration. For measuring voltage dip on voltmeters the stop is designed to push the pointer downscale. Measurements are made by successively setting the adjustable stop until a position is reached where the indicating pointer barely moves in response to a current or voltage impulse. The instrument then indicates RMS current or voltage. Typical applications of the new instruments are measurements of welding current, motor-starting current, and voltage dip. With this type of ammeter and a current transformer, welding currents of three cycles (1/20 second) or more duration can be measured. This enables a welding operator to transfer work from one machine to another and reset a welding machine to the proper current for specific materials. *General Electric Company, Schenectady, N. Y.*

## A LABORATORY JOB DONE IN THE FIELD

HAYS PORTABLE COMBUSTION TEST SETS are equipped to handle an accurate gas analysis—right in the field.

Installations become more successful, troublemakers are rapidly exposed; guesswork becomes a thing of the past.

Test Sets are available with all necessary equipment for the analysis for $CO_2$, CO, and O—complete with flue gas thermometer, and draft gage. For further particulars—write to 925 Eighth Avenue, Michigan City, Indiana.

The HAYS CORPORATION
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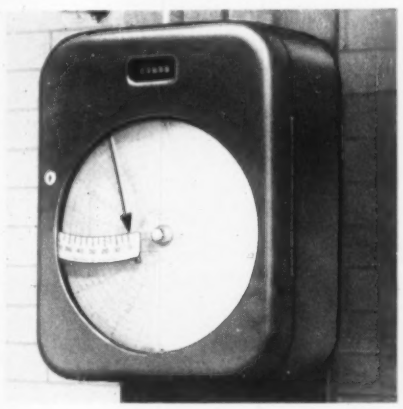


## How Important Is *Accuracy?*

WITH electric flow meters there must be no chance for lag or error in recording or integrating flow, for the cumulative effect of even slight discrepancies will be sufficient to make valueless the records upon which management must depend for important decisions.

Cochrane Electric Flow Meters, which are operated by the galvanometer-null principle, are guaranteed for their accuracy and dependability. They are reliable guides for compiling records of consumption, intake, output and variations in the rate of flow of steam, gases, water and other liquids.

*Write for Publication No. 2006.*

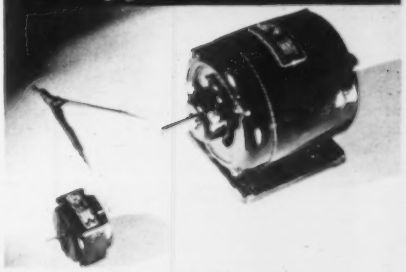
**COCHRANE CORPORATION**
3120 N. 17th St., Philadelphia, Pa.

COCHRANE
FLOW METERS


## Operation Analyser for Oil Circuit Breakers

The circuit breaker operation analyser fulfills the need for an instrument to guide the maintenance man in making the proper adjustments quickly, economically, and positively, and at the same time providing a permanent record of the mechanical condition of the oil circuit breaker both before and after overhauling. This analysing device consists essentially of two main elements: A vertical drum carrying a ruled chart, driven by a synchronous motor through suitable gear reductions, and a pencil stylus operated through a reducing mechanism by the lift rod of the oil circuit breaker. The rotary motion of the drum gives time in cycles (60 cycle basis) as the abscissa on the chart, while the ordinate of the chart represents the travel of the circuit breaker contact mechanism. *Cincinnati Clock & Instrument Co., 1112 Harrison Ave., Cincinnati, Ohio.*

## INSTRUMENT MOTORS
### All Types — All Sizes



**1/2000 to 1/6 Horsepower**

Whatever your requirements, there is a Bodine motor to fit the job. The Bodine line includes split phase, capacitor, and polyphase induction and synchronous a-c motors; shaded pole a-c motors; shunt and compound d-c motors; and series universal motors. Also speed reducer, and governor controlled motors. The finest instruments are Bodine equipped.

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Motor Booklet

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2244 W. Ohio St., Chicago
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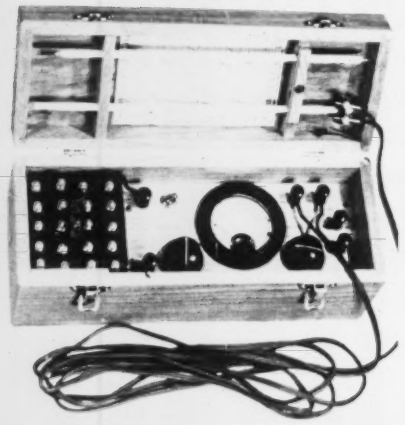
BODINE

## Thermo-Anemometer

The new Thermo-Anemometer is an easy-to-use electrical instrument for the measurement of air velocities over an unusually wide range—from 10 to 6000 feet per minute. It is unique in its accuracy at extremely low velocities, and is suitable for either field or laboratory use in open air, in front of grilles or registers and in ducts. The instrument is housed in an attractive polished oak carrying case (13¼" × 5" × 5") with chromium plated hardware, and weighs only 7 lbs. complete with long-service battery.—*Julien P. Friez & Sons, Baltimore, Md.*



## Thermometer & Pressure Gage

The new line of temperature and pressure recorders, indicators and controllers include thermometers indicating and recording types for temperatures from —40° up to 1200°F. and indicating or recording pressure and vacuum gages for ranges from 6 lbs. of water up to 2500 lbs. per square inch and on vacuum ranges of 10 inches of mercury and over. All types are offered in one, two or three pen models. The powerful, flat, spiral actuating elements have ample pen torque without sacrificing speed of response. Especially heat-treated to insure permanent calibration, they have exceptional over-range capacity. A special safety link between actuating element and pen provides an overload safeguard protecting the mechanism from damage if the pen is moved in either direction manually. Chart is firmly secured to driving mechanism by tapered stud and tapered chart positioning stud, eliminating chart knob and chain. Charts, when renewed, are automatically in time, as the tapered position stud is in effect the hour hand of the electric clock. If current failure makes it necessary to reset chart to correct time line, a friction clutch permits manual rotation for chart setting.—*Brown Instrument Co., 4782 Wayne Ave., Philadelphia, Pa.*

**Vacuum . . . Thermocouples**

A COMPLETE LINE

*embodying many unique features*

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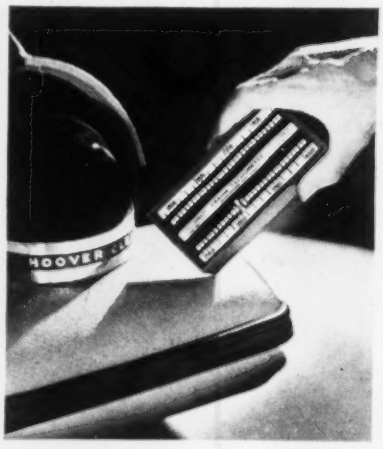
- DEPENDABLE STABILITY
- MORE EFFICIENT
- HIGHER OVERLOAD
- FASTER RESPONSE
- SMALLER SIZE—½"x1"
- LOWER COST

These thermocouples will meet the most rigid specifications. Prompt delivery is assured. Write your requirements to:

**AMERICAN Electrical Sales Co., Inc.**
67 E. 8th St. New York, N. Y.



**MEASURE R. P. M.**
without even seeing the rotating element

**THE "FRAHM" TACHOMETER**

operates merely by being held against or mounted on the machine under test and imposes no load. There are no belts, gears or electrical connections—simply a set of accurately tuned steel reeds which operate by resonance. Various ranges from 900 up to 30,000 r.p.m. Unique for measuring vibrations per minute.

*Write for descriptive Bulletin 1590-I*

**JAMES G. BIDDLE CO.**
ELECTRICAL INSTRUMENTS
1211-13 ARCH STREET PHILADELPHIA, PA.

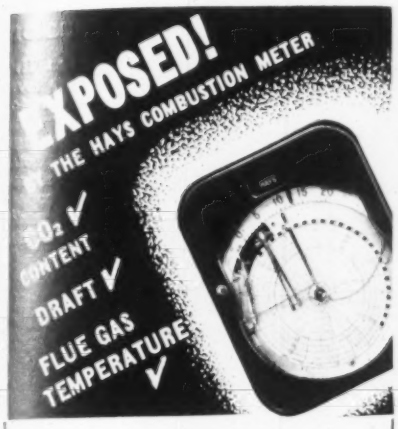
## Chemical Analysis Record

Applying the Dropping Mercury Electrode principle of analysis, L&N's new Electro-Chemograph automatically inks curves from which quantitative and qualitative analyses can be determined. Making possible quick

and convenient analyses in those processes where its possibilities have been determined, the method eliminates dark rooms, developing processes and delicate galvanometer systems. Drawn in sight of the operator, the curve is inked on a wide, easily-read, permanent chart. Instruments are made up of standard L&N mechanisms.—*Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.*

## New Brinell Machine

Of particular interest to those Brinell testing large and awkward parts such as castings, forgings, etc. is a new Brinell Machine having a large stationary table and a ram sufficiently long to cover the range of the machine. The work is simply placed on the table and the ram carrying the test-ball brought into contact with it. Operation is controlled by a lever on the side of the machine and the ram may be stopped in any position. Thus when several pieces of the same size are to be tested the ram is raised only enough to remove and insert the work. Movement of the lever rapidly adjusts the ram for work of different sizes. This takes less than ten seconds from one extreme to the other. While the ram movement is rapid the actual test is applied at a relatively low speed thus avoiding impact errors. Operation is hydraulic throughout and a fractional H. P. ball-bearing motor drives the pump, the shaft of which, is also ball-bearing mounted. All working parts are bathed in oil insuring long wear and minimum of maintenance. Two standard sizes are available: No. 1 has a throat depth of 6", maximum height 12". Table 12" × 20". No. 2, throat depth 9". Maximum height 18". Table 17" × 24".—*Detroit Testing Machine Co., 5147 Trumbull Ave., Detroit, Mich.*




A 24-HOUR RECORD—giving accurate and dependable measurements so vital to efficient and economical operation.

Hays Combustion Meters employ the Orsat principle for measurement of $CO_2$. Water operated — no moving parts—extreme accuracy coupled with dependable performance.

There is a Hays Combustion Meter to fit every requirement—remote or integral mounting, indicating or recording or both. Write to 925 Eighth Avenue, Michigan City, Indiana, for free catalog.

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MICHIGAN CITY, INDIANA, U.S.A.



PORTABLE
WHEATSTONE BRIDGE

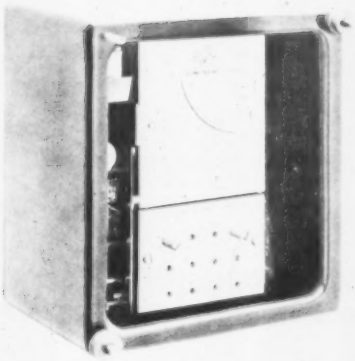
A high grade instrument for measuring resistances from a fraction of an ohm to 10 megohms. Contains a 4-dial rheostat, ratio dial, galvanometer and battery, all enclosed in a substantial walnut case. Nine coils per dial. Accuracy 1%.

Cat. No. 1050—Portable Wheatstone Bridge with Murray and Varley Loops $110.00

Cat. No. 1052—Portable Wheatstone Bridge without Murray and Varley Loops $90.00

Send for Bulletin No. 105

RUBICON COMPANY
*Electrical Instrument Makers*
29 North 6th St. Philadelphia, Pa.

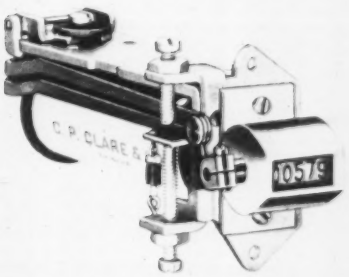



## Protective Relay

This relay is designed for the protection of a.c. apparatus which is subject to overloads, either momentary or continuous. The time delay element is a new type of device consisting of a heater and Bi-metallic strip combination, fully compensated for ambient temperature. Thus the relay can be located anywhere remote from the apparatus being protected and always operate on current values directly without influence from any other variables. The heating rate of the bi-metallic strip is controlled so as to match approximately the heating rate of windings of the protected apparatus. The instantaneous element operates at 10 times the minimum operating current which is determined by the tap setting.—*Rolfe-Smith Co., Bethlehem, Pa.*

## Electric Counter

Electric counter, capable of counting up to 600 counts per minute, is illustrated. They measure 1¾" wide by 2" high by 1⅞" long, thus being conveniently arranged




for panel mounting. Type C is for d.c. up to 110 volts; type A is for a.c. up to 110 volts, 60 cycle.—*C. P. Clare & Co., Lawrence and Leaon Aves., Chicago, Ill.*

## Resistors for D.C. Operation

Type FL Resistors, listed under the Underwriters Laboratory Re-examination Service and specifically designed for approved auxiliaries for d.c. operation of fluorescent lamps, are so constructed as to provide maximum heat dissipation in minimum space. They are of the insulated wire wound type, with 1,250 volt insulation. They will operate at a temperature rise of from approximately 100° to 120° F. with standard auxiliaries. They are encased in metal boxes of special ventilated construction and sufficiently small to fit in any fixture channel. Overall box dimensions are approximately 6⅝" x 1¾" x 1¼". Total assembled weight of the unit is less than 12 ozs.—*International Resistance Co., 401 N. Broad St., Philadelphia, Pa.*


WHEELCO
SURFACE TEMPERATURE
PYROMETER

A light weight, precision built, self contained pyrometer with open faced, easily-read scale for temperature reading of all surfaces (stationary or moving). Commonly used on plastic, paper and textile mill rolls, motors, bearings, etc. Adjustable joint has 180 flexibility, for positioning to convenient working angle.

*Write for Complete information*

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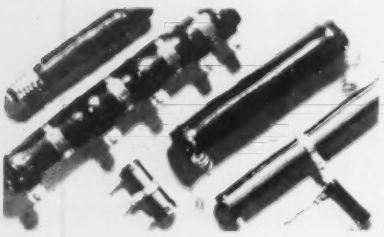
20 WEST 47th ST., NEW YORK

## Resistors

New vitreous enameled wire wound resistors are illustrated below. Years of intensive research has been spent in development work on refractories, wire processing and enamels, producing a crazeless enamel structure that withstands humidity, moisture, immersion and numerous other specified tests. *Ward Leonard Electric Co., 38 S. Str., Mount Vernon, N. Y.*



## Vacuum Tube Voltmeter

The new Model 120 vacuum tube voltmeter combines many new features in vacuum tube voltmeter design. The ability to measure high frequency a.c. and high voltage d.c. combined in one instrument extends its usefulness to all types of radio and television servicing. The high frequency

input is through a low capacity Type 955 tube at the end of a four foot connecting cable so that the input capacity and load effect is reduced to a minimum. The actual input capacity being somewhat less than 5 micro-micro-farads. The high frequency has four ranges from 1½ volts full scale to 150 volts and negligible frequency error to over 100 megacycles. High frequency voltage as low as 0.05 volts can be read directly on the scale. The input is strictly capacitive and no return d.c. path is necessary. The d.c. input has 8 ranges from 5 to 7500 volts with input resistance of 25 megohms to 250 volts and 700 megohms up to 7500 volts. The calibration of all a.c. and d.c. ranges is entirely independent of line voltage fluctuations from 100 to 130 volts. There is a single zero adjustment for all ranges a.c. and d.c. which does not have to be reset when changing ranges. When operated as a d.c. vacuum tube voltmeter voltages may be measured either positive or negative with respect to ground without reversing the leads. The circuit design is such that accidental overload can in no way damage the meter or equipment. — *Hickok Electrical Inst. Co., 10531 Dupont Ave., Cleveland, O.*


# SOLU-BRIDGE

## SOLUTIONS TESTER

The smallest solutions conductivity bridge available—the simplest in operation—and the lowest priced!

The SOLU-BRIDGE is primarily designed to determine the concentration of alkali washing solutions of the type used in the laundry, dairy, brewery, soft drink industries, in metals cleansing, and similar applications. Panel scale is calibrated directly in percentage of sodium hydroxide, so that measurements are made easily and accurately without any complications.

Ruggedly built, completely self-contained, operates from 110 volt A.C. line. Size only 6¾" x 5" x 2⅝".

Model RD-1, illustrated ..... **$25.00**

Dip Cell, at left of illustration ..... **$7.00**

*For complete details, write for Bulletin RD-100.*

**Industrial Instruments Inc.**

156 Culver Avenue, Jersey City, New Jersey



# TEST MAGNETIC PROPERTIES OF YOUR STEELS

THE ONLY SINGLE BUTTON ELECTRICAL RETURN FLUXMETER

SIMPLEST AND MOST EFFICIENT

*Bulletin 504*

THREE DIFFERENT STYLES

Portable Standard with single electrical zero return.

Switchboard Type with above zero feature located on flexible lead for bench operation.

Two Button Pointer Shift in place of our patented standard zero return at a lesser cost.

*Acknowledged leaders in development of high sensitivity meters*

**Rawson Electrical Instrument Company**

110 POTTER ST. CAMBRIDGE, MASS.

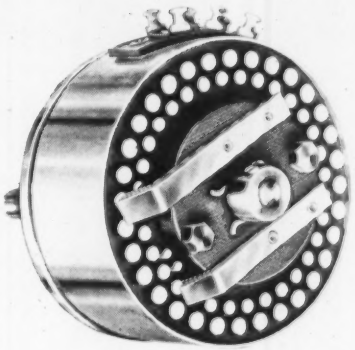
Branch: 15 East 26th Street, New York City

Representative: E. N. Webber

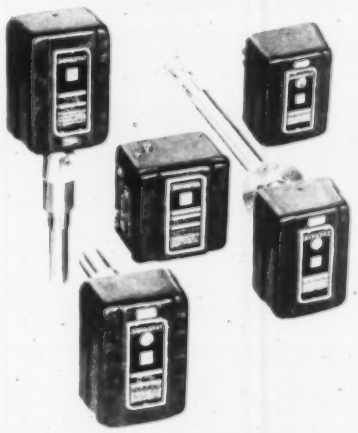
1313 W. Randolph St., Chicago, Ill.


## New Stud Type Attenuator

A stud-type Attenuator known as Type B-31 especially suited for low work has a spiral clockspring contact used in each arm of the bridged "T" mating two series pressure contacts, making possible a maintained low level of −150 DB. Noise is further reduced by a contact of laminated beryllium copper operating over beryllium copper studs. 30-step attenuation is provided, 2



and attenuation is linear for 24 steps, 1.5 DB per step up to 36 DB, tapering off to 6.5 DB on the next to last, and to infinity on the last step. Standard impedances for the bridged "T" and ladder networks are 50, 200, 250 and 500 ohms.—*International Resistance Co., 417 N. Broad St., Philadelphia, Pa.*



## Limit Controls

New line of limit controls includes new models of maker's "Pressuretrols" and "Aquastats" now available, also of "Airstats" and "Furnacestats" to be available September 15th. Among features common to all four new models are the following: Ample terminal spacing with mounting which can be made in less space. Simplified differential adjustment mechanism on mercury-switch furnace controls and "Aquastats" whereby differential can be changed instantly with one finger; this mechanism imposes no strain on the bimetal helix measuring element. Visible scales and external adjustments. In the "Pressuretrols" the bellows are located within the cases. Furnace controls, ball-and-socket and stud have been radically reduced in size, all friction losses have been minimized. By new method of mounting "Surface Aquastat" pipe straps are concealed and friction coil permits installation on vertical, horizontal or angle pipes. "Immersion Aquastats" are now available for both horizontal and vertical mounting. — *Minneapolis-Honeywell Regulator Co., 2953 Fourth Ave., South, Minneapolis, Minnesota.*

## WEAR—TOUGHNESS MEASUREMENTS

*Type J Taber Abraser Testing Outfit*

Taber ABRASERS are calibrated for standard wear measurements on paint, lacquer, molded or laminated plastics, electroplate, porcelain enamel finishes.

Other Models available for Woven and Knitted Fabrics of wool, rayon, silk, etc.

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**TABER INSTRUMENT COMPANY**
NORTH TONAWANDA, N. Y.

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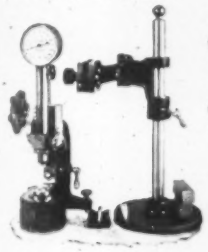
done WITH NO MENTAL HAZARDS. The SCLEROSCOPE has done it for the past 30 years.



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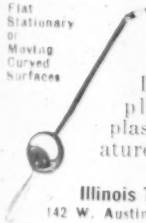

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Ideal for rolls, molds, plates, platens and plastic material temperatures.

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142 W. Austin Ave. Chicago, Illinois

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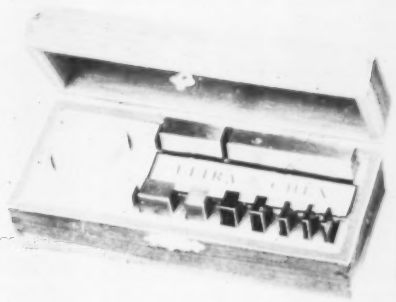
## RHEOSTATS

*Ask for Catalog No. 5*
National Electric Controller Co.
5317 Ravenswood Ave., Chicago, Ill.


## Precision Length Standards

A new set of precision measuring standards consists of nine standards ranging in millionths of an inch and will measure combinations in steps of 1.10" up to 1.9" and 11 combinations in steps of 1.10" up to 1.1". Also available is an outfit of ten gauges accurate to plainness within 1 millionth



This is used to check the parallelism of micrometer anvils by observing light interference bands on both anvils.—*George Scherr Co., Inc., 128 Lafayette Street, New York, N. Y.*

## X-ray Diffraction Unit

Smaller and more versatile than previously-available outfits of this general type, new "XRD" x-ray diffraction unit includes transformer housing, transformer unit, control unit, cooling-water protective relay, diffraction instrument supports, x-ray tube casing and support, radiation shields and line cable. It is regularly available for operation on 100-130-v or 200-250-volt 50-60-cycle a.c. It embodies provisions for operating the most powerful commercially-available x-ray tubes, but is entirely shock-proof. Energizing equipment, enclosed in steel cabinet, is constructed to absorb shocks accompanying line surges, etc., which would shorten useful life of x-ray tube. Control equipment is mounted on swinging panel which serves as cabinet door. Unit is mounted on rubber-wheeled castors, can be used at any point where gas and water connections are available. An electric clock is wired into circuit for timing exposures and keeping records of tube performance. Instrument supports consist of four independently adjustable tables, each adjustable in height and tilt, each with camera track pivoted at tube casing end, thus providing all three adjustments required for perfect alignment with x-ray beam, permitting simplification of accessory instruments.—*General Electric X-Ray Corp., 2012 Jackson Ave., Chicago, Ill.*

## 50-Watt Rheostat

Unique construction of the 50-Watt all metal rheostats IRC Type PR-50, makes possible operation of the rheostat at full load in any portion of the resistance winding down to 25% of full rotation without exceeding the normal temperature rise by more than 30° C. The 50 watt rating is based on a hottest spot temperature rise of 110° C. when unit is mounted on a metal panel and power dissipated over the entire unit. Thus, this rating applies under the same mounting conditions for as low as 25% of full rotation with a temperature rise of only 150° C. Rheostat is only 2⅜" in diameter. Depth behind panel is 1⅝". It is available in a full range of values from 0.5 ohms to 10,000 ohms.—*International Resistance Co., 13 N. Broad St., Philadelphia, Pa.*

## AC-ME RECORDING GRAVITOMETER

ACCURACY
*with*
SIMPLICITY
*for*
RECORDING SPECIFIC GRAVITY OF GASES

— FEATURES —

Requires minimum of maintenance

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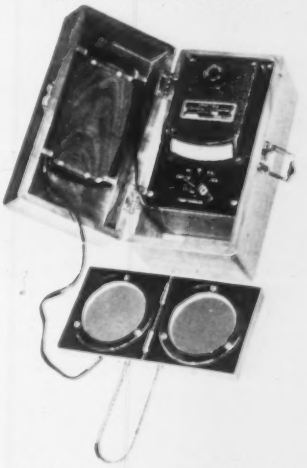
**UNIVERSAL PHOTOMETER**
(FOOT CANDLE METER)



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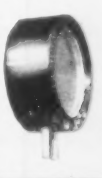

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**ELECTROCELL**
Self-Generating Photocells
Great variety of sizes
Mounted or unmounted

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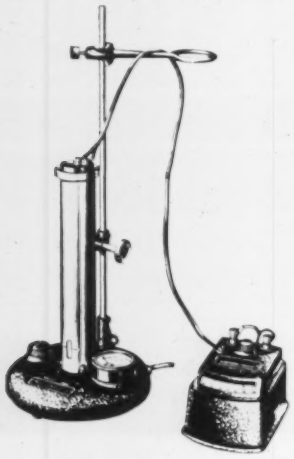
## Capacitor Selector

An ingenious capacitor selector to get the capacitor-type motor going without delay, important in refrigerator servicing is illustrated. This unit is simply a multiple-section capacitor including a 65 mfd., a 35 mfd., and several 17½ mfd. sections, providing any capacity from 17½ up to 152½ mfd. The needed sections can be joined in parallel simply by plugging their corresponding colored plugs into a grouping connector. At a glance the user can tell just what total capacity is being introduced in the motor-starting circuit by means of the clip terminals of the attachment cord. The selection of just the right capacity is essential for proper motor-starting characteristics and for economical capacitor life. Insufficient capacity results in excessive peak voltage which soon "cooks" the capacitor. Excessive capacity reduces starting torque and prolongs starting, the latter being detrimental to capacitor life. With the Aerovox capacitor selector just the right capacity to strike a compromise between adequate torque with quick starting, and economical capacitor life, is attained.—*Aerovox Corp., New Bedford, Mass.*

## Photoelectric Turbidimeter

High sensitivity is the chief feature of this new turbidimeter. The measurement of a very small amount of total suspended matter in a solution is achieved by direct light transmission through the solution to a photoelectric cell. Sensitivity is amplified by a reflector tube with polished bore suspended in the solution through which the transmitted light passes. Distance between cell and light source may be adjusted to cover a wide range of relative turbidities. It



is claimed that this instrument will detect a variation of one part per million of suspended silica throughout a range of from 1 ppm. to 200 ppm. The instrument may also be used for determining sulphur concentrations in test samples containing from 0.1 to 3.0 mg. of sulphur.—*Parr Instrument Co., Inc., Moline, Ill.*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*Wheelco Series 3200*

**POTENTIOMETER CONTROLLER**

Matching the unusual sensitivity of the Famous CAPACITROL control system with the well established accuracy of the potentiometric method of temperature measurement, Wheelco again leads in supreme performance by offering this unbelievable solution for control problems of extreme accuracy and sensitivity.

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HAYS DRAFT GAGES are offered in a wide variety of types from the V-type, illustrated above, to recording gage. Send for our catalog today. Write to 925 Eighth Avenue, Michigan City, Indiana.

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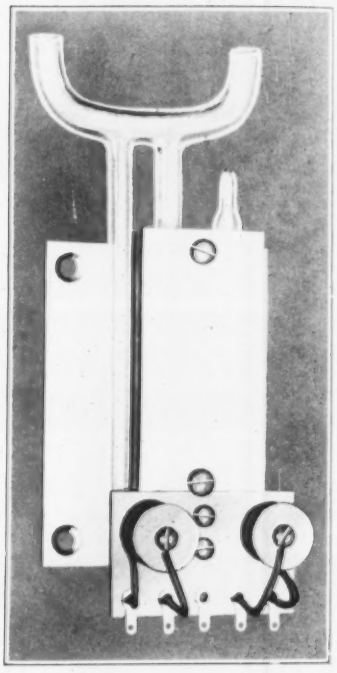
## Quartz Gas Analysis Ce

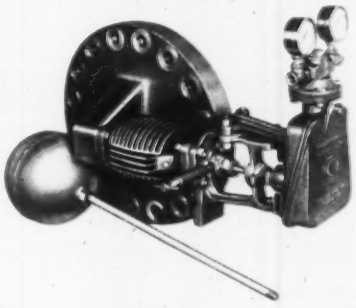
The new all quartz cell for use in analysis work was developed primarily analyze for corrosive gases such as SO$_2$ H$_2$S. Since the gas does not come in tact with metal at any point in its sage through the unit there is no possibility of corrosion taking place and quently effecting the accuracy of the quartz protected platinum spirals mounted in quartz. This complete unit then surrounded by a metal of high conductivity in order to get proper dis tion of heat. The principle of the un



based upon the thermal conductivity method. A thermostatic box is recommended for all installations to insure most satisfactory results.—*Charles Engelhard, Inc., 233 New Jersey R. R. Ave., Newark, N. J.*

## Liquid Level Controller

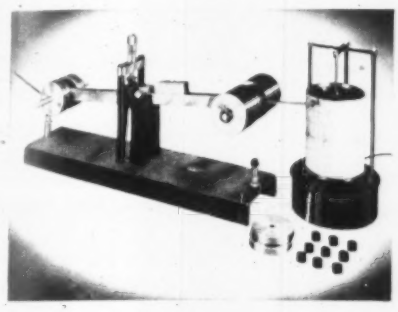
Newly developed liquid-level controller illustrated, is an internal float type, flange mounted controller designed for use where an external float cage type liquid level controller with equalizing connections cannot be used due to the possibility of an exces-



sive amount of solid matter settling in the float cage. It also is suitable for use when the material being handled might congeal. Controller is made in several types and can be furnished with either 8" or 10" mounting flange. Radiating fin stuffing boxes with greases seal lubricators can be supplied when the service conditions warrant. When equipped with the McAlear No. 95 Control Pilot, as shown in the illustration, this controller will consistently maintain a definite liquid level or a definite variation of liquid level regardless of flow conditions.—*McAlear Mfg. Co., 1961 Western Ave., Chicago, Ill.*

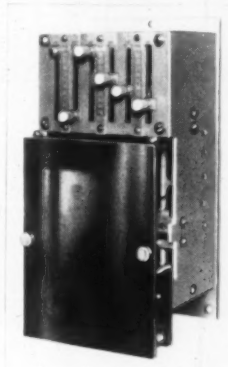
## Rubber Oscillograph

...instrument for rubber technologists ...chanical engineers for use in deter... ...certain mechanical properties of ...and rubber-like materials as vibra... ...sorbers, may be used to measure ...characteristics cloading and unload... ...cup under a given dead load; and ...and dynamic characteristics (energy ...ation during impact loading; resili... ...and effective dynamic modulus. The ...graph is complete in itself and pro... ...an autographic record in a few minu... ...on which can be evaluated the prop... ...mentioned above. The instrument can ...used also as a valuable auxiliary to a ...machine to evaluate a test piece pe... ...ally throughout the duration of a Le... ...Laureau Instrument Co., 9618 Geor... ...Ave., Silver Spring, Md.



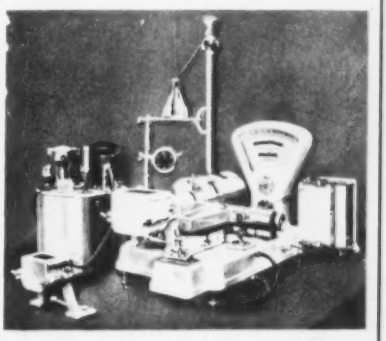
## Instantaneous Reset Timer

New "Multiflex" automatic timer is a synchronous-motor-driven reset timing relay especially designed for applications requiring one or more contact operations in a timed sequence. Timers for controlling from one to six circuits may be supplied in a single unit with the opening and closing of each circuit independently adjustable. Unit consists of a moving plate driven by a synchronous timing motor through a solenoid-operated clutch. Contacts are closed and opened with a quick make and break action as this plate is driven downward. When clutch is disengaged plate is reset by a spring. Less than ½ sec. is required for resetting from longest possible cycle for which timer can be set. Several control circuits for the clutch coil are available. Each



circuit contact has "on" and "off" indicators which are adjustable along a linear time scale by loosening a thumbscrew. The "on" indicator is adjusted to the division corresponding to time when circuit is desired to close after timing interval has been started. Likewise, "off" indicator is moved to the time when circuit is to be open. "On" and "off" indicators for each circuit can be adjusted independently of each other to close or open their respective circuits in any desired sequence. Vernier adjustments (not illustrated) can be provided where "extremely accurate" time adjustments are required. These consist of adjusting knobs located above the time scale for each contact. One complete turn of knob advances indicator one division on the linear scale.—*Eagle Signal Corp., 262 Twentieth St., Moline, Ill.*


## PLASTOGRAPH



Recording Plastometer—based on the dynamometer principle and practically "weighing" the plasticity of the different materials. Measures consistency over a wide range of materials—from fairly viscous, syrupy substances to unvulcanized rubber. Has been applied successfully in RESEARCH as well as in PLANT CONTROL (for continuous operation) in the following industries:

RUBBER — CELLULOID — ARTIFICIAL SILK — PHOTOFILM — ACTIVATED CARBON — PAINT —FERTILIZER—STARCH—DEXTRIN AND GLUE —TAR—ASPHALT—As well as for TESTING OF SOILS for Highway Building . . .

Can be supplied with various types of mixers or agitators—all water jacketed for efficient temperature control. Has three different sensitivity settings and can measure and record within each desired range with three times and five times increased sensitivity by the simple expedient of zero-suppression.

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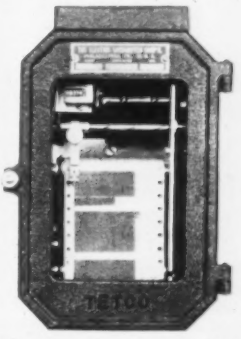
## TETCO
## Speed Recorder

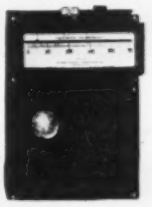


Creates a permanent time record on a waxed chart. Accurately records rate of production, time and duration of stops, total quantity produced.

**The Electric Tachometer Corp.**
1358 Spring Garden St., Philadelphia, Pa.



## ALNOR Electronic Type PYROMETER CONTROLLER



For all industrial applications

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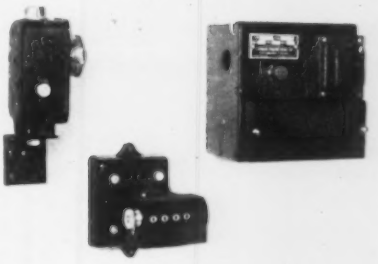
## Photo Electric Counter

Photo-electric amplifier contact relay unit, terminal board, power transformer for amplifier and light source are all mounted as integral parts of photo-electric amplifier unit cover. Photo-cell is mounted 1" from opening, minimizing effects from stray light. One tube of standard type is used, having within it both rectifier and amplifier elements. Operation is direct current which allows maximum sensitivity and ease of maintaining adjustment. As sensitivity control is provided, unit will operate on visible or invisible light. Control relay is plug-in type and can be removed the same as a tube for inspection or replacement. A pair of contacts is provided on relay that are closed when light is on cell. When the light is cut off these contacts open and an additional pair of contacts close. The contacts will make or break and carry 3 amp. at 110 volt A.C. Estimated tube life 2,000 to 10,000 hours. Equipment is tested for speed of counts up to 600 per minute and is supplied complete with four-digit counter and Light Source.—*Lipman Engineering Co., 115 Van Braam St., Pittsburgh, Pa.*

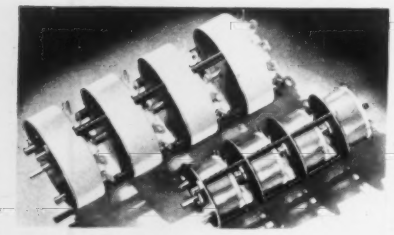


## Aircraft Direction Indicator

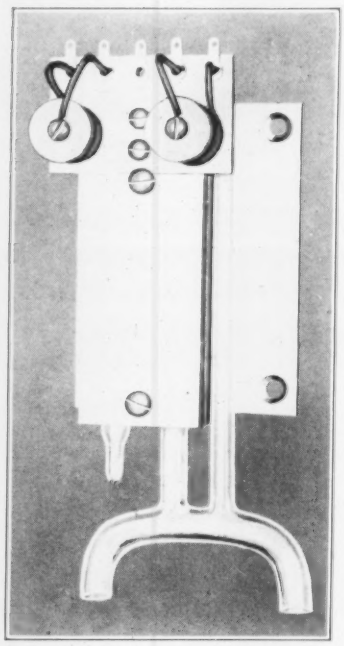
New long-period compass-type direction indicator, "Type 158E," is announced as an aid to pilots and navigators. Said to be unlike all previous compasses of this type, it has a moving pointer, which continuously indicates direction against a fixed dial. This obviates setting verge ring for each course, also permits observer to know instantly heading of airplane if he inadvertently deviates from required course. Parallel reference lines and index may be set to facilitate compass reading over long periods of time. By using a fixed dial, reference to a map or chart is said to be made easy because layout of the dial corresponds exactly to that of the compass rose on maps and charts. Parallax is said to be completely eliminated. It is said that when new direction indicator is subjected to the standard swirl test "no error is observable" and when tested under actual service conditions in rough air it is "extremely stable."—*Kollsman Instrument Co., Inc., 80-52 45th Ave., Elmhurst, N. Y.*

## Power Tap Switches

Tandem assemblies of 2, 3, 4, or more of the new Ohmite Power Tap Switches are now available. These tandem assemblies are used to switch both sides of a single-phase line or to switch all phases of a 3-phase line, to provide simultaneous control of separate circuits, and for other applications. Ohmite power tap switches—coupled together by special extended shafts—are used in these tandem units. They are compactly assembled, and held rigidly together by throughbolts and insulated spacers. Easily mounted on panel by 3 screws.



Four sizes of Ohmite power tap switches are available for single or tandem mountings: Model 212, 10 amps., 240 volts a.c., diam. $2\frac{1}{4}$". Model 312, 20 amps., 240 volts a.c., diam. $3\frac{5}{16}$". Model 112, 40 amps., 240 volts a.c., diam. $4\frac{5}{16}$". Model 608, 75 amps., 240 volts a.c., diam. 6". *—Ohmite Mfg. Co., 4835 Flournoy St., Chicago, Ill.*

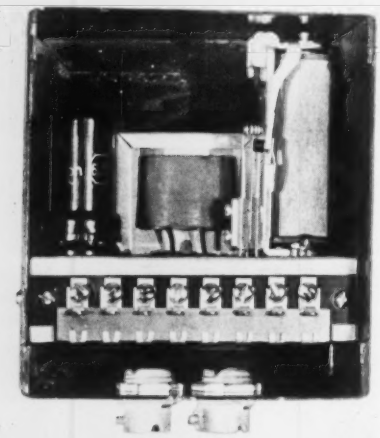
# ANALYZE CORROSIVE GASES

● The Englehard All Quartz Thermal Conductivity Gas Analysis Cell is the answer to corrosion problems. The gas does not come in contact with any metal at any point in its passage through the unit. Positive calibration and continuous accuracy is assured.

*Send for Bulletin No. 800.*

**CHARLES ENGELHARD, INC.**

90 CHESTNUT ST., NEWARK, N. J.

## Electronic Switch

The new Model ES-15 electronic switch, designed to eliminate the possibility of contact arcing and welding on such equipment as thermostats, limit-switching mechanisms, contact making devices requiring very low contact pressure and limited movement, employs an electronic tube to actuate a circuit relay. Input such as through the contact of a thermostat, is connected to the tube which requires a control current of about one micro-ampere, and which permits a contact resistance to one megohm. This slight current is amplified to operate the single pole double throw relay. The relay contacts are rated at 3 amps. on 110 volt 50 or 60 cycle non-inductive a.c. They are then connected to the electric equipment that is to be controlled. Power is from 110 volt line 3 watts. Overall dimensions are 5¼ × 5⅝ × 3⅝ inches. Operation can be maintained at speeds to 900 complete cycles per minute. In addition to the usual application in control of mechanisms, the switch can be used to control chemical solutions such as acids and alkalies or any high or low-resistance substance that can be regulated electrically. This unit may also be used to control machines and can replace meter relays on many types of instruments.—*United Carr Fastener Corp., 44-37 54 St., Long Island City, N. Y.*

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A single RED line . . . can save you money, eliminate errors and assure temperature accuracy, which is so important in all manufacturing processes.

Palmer's "Red-Reading-Mercury" Thermometers can be read quickly, at a distance, in all kinds of light. They are annealed and treated so as not to change with age or use and to give longer service.

Be safe! Install PALMER thermometers with the wide RED column for best results!

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2511 NORWOOD AVE., CINCINNATI, NORWOOD, OHIO.

*Manufacturers:* ALL TYPES THERMOMETERS *Branch:* KING & GEORGE STS., TORONTO.

# Instruments In Power Control

By W. B. SKINKLE

Secretary and Engineer, Pittsburgh District Power Committee, Subsidiary Companies of U. S. Steel Corporation, Pittsburgh, Pa.

Paper originally read before the Conference on Instrumentation in the Steel Industry at the Carnegie Institute of Technology, October 12-14, 1938.

TO COVER the entire subject of instruments to control power in the steel or any other industry would be beyond the ability of any one man. The writer will discuss a few definite examples within his experience, showing what has been accomplished through the application of instruments to control both power generation and power consumption.

Instruments for indicating, recording and controlling such variables as temperature and flow have been standard equipment for so many years that we need not go into their use. There is, however, a class of instruments that has been coming into use recently, on which large returns can be made. These help control costs chiefly through proper *timing* of the various manufacturing operations.

It is remarkable how seldom a sequence of operations is timed in such manner that the lowest costs will result, and how much the lack of proper timing increases industrial costs. It is believed that much less thought has been given to this subject than it warrants.

As an example, let us take the cost of purchased utility power. The rate schedule of almost any public utility company can be subjected to exact mathematical and graphical analysis. Fig. 1 is a typical rate graph, where total cost of power in dollars per month is used as the ordinates, and energy consumption in kw. per month as the abscissa. The family of lines shows how the monthly power bill increases with continued use of energy at some particular demand. This graph is intentionally made with large intervals between demands for which lines are drawn for the purpose of illustrating the principle and for easy reading.

The chart shows that if 1,300,000 kwh. of energy were purchased during a given month at a demand of 5,000 kva., the resulting power bill would have been about $17,400.00 for the month. The chart also shows that had this number of kwh. been purchased under ideal conditions of 100% load factor, the demand would have decreased from 5,000 kva. to slightly less than 2,000 kva., as shown at "F" and the power bill would have decreased from $17,400 to about $12,200 a month—a monthly reduction of about $5,200 or 30%. While the use of energy under such perfect conditions is impracticable, efforts to approach perfection will result in substantial cost reductions.

The usual method of determining the demand imposed on a utility by a customer is through a demand meter which draws a series of arcs. The length of arc, when multiplied by the proper "meter constant," determines the kw. or kva. demand during each demand period. The longest of these arcs in a given month is usually the base on which the demand charge is calculated. This demand charge ranges anywhere from $1.00 to $2.50 per kw. per month and constitutes anywhere from 40% to 75% of the total power bill.

Fig. 2 exemplifies conditions before control of demand and timing of production. It shows short sections of six monthly demand records that set the monthly demand charges on a particular plant. It covers the worst six months of a given year. A study of that plant indicated that the required production could be maintained without undue trouble or interruption at 2,400 kw. demand. (This controlled demand is indicated by the heavy horizontal lines.)

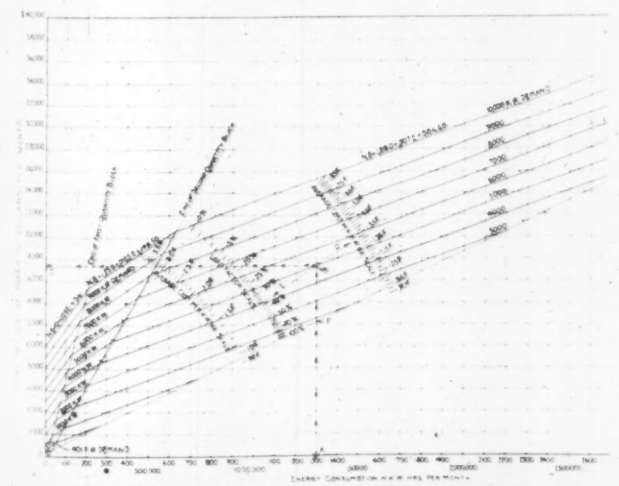


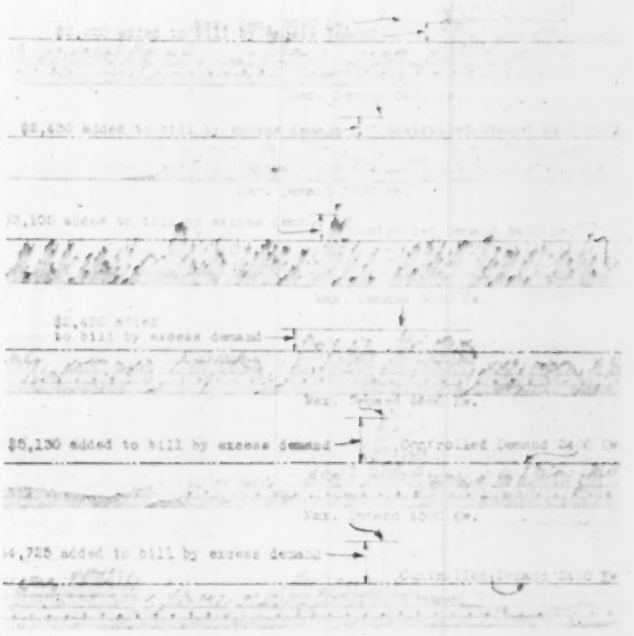
Fig. 1. Graphic determination of wholesome power costs.

$5,430 added to bill by excess demand
$3,105 added to bill by excess demand
$2,430 added to bill by excess demand
$5,130 added to bill by excess demand
Controlled Demand 2400 Kw
$4,725 added to bill by excess demand

Fig. 2. Typical demand curves.

Some plant managers start "campaigns" toward the end of each month and insist that their department heads "get that order out and into this month's business." It only takes a glance at the top of Fig. 2 to visualize such a "campaign" in this Works, and the response to the pressure. False economy, through poor timing, is evident. The areas represented by the demand lines above the "controlled demand" did not increase the plant production for the month by more than a small fraction of 1%, but the excess demand thus created increased the monthly power bill by $2,200. It is doubtful whether the total sale price of the added production equalled the increase in the power bill! The other chart sections show similar increases in power costs:

(B) A 1½ hour peak added $2,430 to the month's bill.

(C) A 1¾ hour peak added $3,105 to the months bill.

(D) A "good" day's production added $2,430 to the bill.

(E) A short-time peak due to a turbine break-down when the entire load was thrown onto the utility added $5,130 to the month's bill, and most of this was added during one hour of the peak. The energy shown in the peak was calculated and divided into the increase in cost due to the peak. This extra energy was found to have cost nearly $1.19 per kwh.

(F) A peak of only 1½ hours added $4,725 to the month's bill.

Now let us examine the sensational results accomplished by installing a few relatively simple devices.

A standard demand limiter costing approximately $300 was installed on the incoming utility power lines, and some standard time switches costing about $30 each were installed near the heating furnaces. The demand device sounded a siren near the end of the demand interval (in this case 15 minutes) whenever the demand threatened to pass a predetermined maximum that had been set by the plant officials at the beginning of the month as sufficient to carry the expected production for that month. The time switches

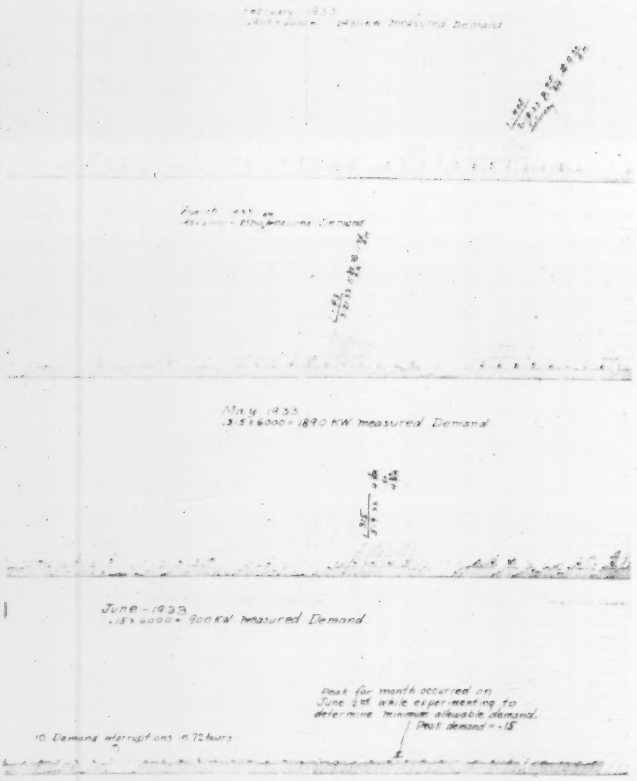

May 1933
3 51/6000 = 1890 KW measured Demand
June - 1933
15 1/6000 = 900 KW measured Demand
Peak for month occurred on June 2nd while experimenting to determine minimum allowable demand.
Peak demand = 15
Demand interruptions 0 72 hours

Fig. 3. Demand curves before and after installation of control instruments.

flashed a red light at the heating furnaces so that the heater would draw blooms not in excess of the maximum rate at which they could be handled by the sequence of mills that formed the material, and in this way prevent partly rolled product from lying on the run-out tables and cooling during the rolling process.

The chart sections in Fig. 3 show the results. The first three records show demands for typical months immediately preceding the installation of the control instruments. The bottom record is typical of demands for the first month the control equipment was in operation. Owing to some special load conditions, it suddenly became necessary to rush the installation which was not completed until late the night of the 31st of the month, and it was placed in regular operation early the next morning. One demand interval "got away from" the operators on the second day, as indicated by the note on the chart.

The maximum demand was, however, reduced from 1,890 kw. for the preceding month to 900 kw. for the first month that the demand limiter and switches were in service. Another interesting feature was that on the preceding month the mill using 1,890 kw. of demand had 15,000 lbs. of scrap, while under the controlled demand of 900 kw. the mill cut its scrap loss in half. Incidentally, a careful estimate showed that a $500 total investment in instrumentation kept close to $7,000 off the power bill that first month.

By the end of the first year approximately $78,600 had been kept off the costs. Work of reducing these power costs continued, and at the end of the second year a careful estimate indicated that approximately $170,800 had been kept off power costs for that year. This last larger cost reduction was due to a large increase in business and a considerable extension of motorized units in the works, which resulted in over

| Month | 1934 Billing Demands | 1935 Billing Demands |
|---|---|---|
| January | 5,233 KW | 2,602 KW |
| February | 5,212 KW | 2,391 KW |
| March | 5,673 KW | 2,311 KW |
| April | 6,148 KW | 2,311 KW |
| May | 6,942 KW | 2,129 KW |
| June | 6,214 KW | 2,125 KW |
| July | 6,456 KW | 2,086 KW |
| August | 6,480 KW | 2,235 KW |
| September | 6,240 KW | 2,160 KW |
| October | 5,520 KW | 2,125 KW |
| November | 5,460 KW | 2,112 KW |
| December | 6,218 KW | 2,178 KW |

Fig. 4. Comparison of demands.

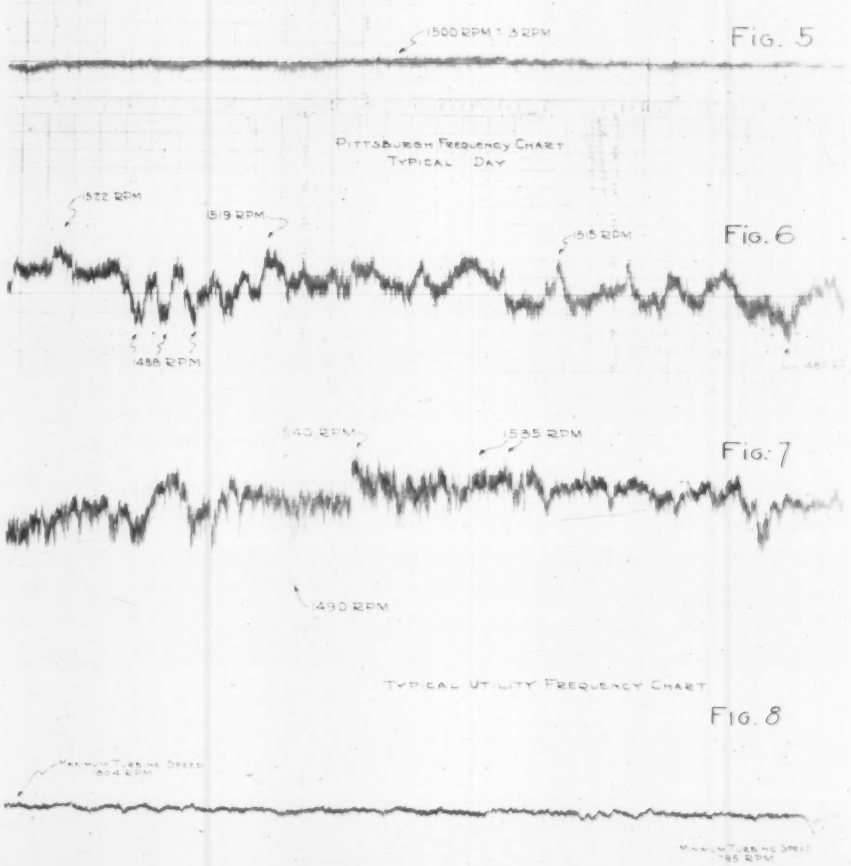
50% increase in the use of electric energy.

An indication of what was done with the demands is shown in Fig. 4, which is a tabulation of the demands of this plant each month for a typical year before and after installing the control devices.

Devices of this type are now standard equipment in all U. S. Steel Corporation plants making any considerable purchases of utility power.

The power requirements of the steel industry have been radically changing during the last few years. We are now requiring power systems to absorb loads that were hardly thought possible as little as ten years ago.

The new continuous mills producing wide flat products such as plate and sheets present control problems that are important to both the engineer and the instrument-maker. Not so long ago a heavy "bite" taken at a mill that put from 6,000 to 10,000 kw. peak load on a system was considered a large peak. Such peaks were encountered during the initial forming passes on ingots or slabs. These ingots and slabs were short, so that the load lasted only three to five seconds. When the piece being rolled lengthened, so did the time required for rolling, but the cross-section area was reduced and so was the power required for rolling.



nsider what happens when a load is suddenly added to emoved from an electric system. A sudden load addition st carried by the kinetic energy stored in the highsped ting parts of the turbine and generator or we might say he "flywheel effect" of these rotating parts. These must up the initial energy through loss of speed. This speed uction causes an adjustment of governors which admit steam to the turbine and equilibrium is thus restored. reverse actions take place when load is removed. "Flyels" give up energy for a maximum of about 5 seconds. he load is sustained for a longer period flywheel energy annot be used efficiently.

In an a-c. system the frequency is an exact measure of the speed of the generators. Fig. 5 shows the frequency on a steel works electric system on July 4 when all main rolling mills were shut down and only crane lifts and similar items caused changes in load. The width of the band is a measure of the sensitiveness of governor and the little peaks and valleys show additions and removals of load. Contrast this uniform speed with that on Fig. 6 which shows a typical mill working day.

When the large 100" plate mill at Homestead was added to the system, no additional generating capacity was added. This mill has four continuous stands and hot steel is in all stands at the same time. It was estimated that the normal load addition thrown onto the system would be from 15,000 kw. to 25,000 kw. at its peak and would last 15 to 20 seconds. The effect of such loads on the system speeds is apparent from a glance at Fig. 7.

Contrast this speed variation with that of our utility companies as shown in Fig. 8 which is part of a chart originally covering three full days. The usual variation is ±0.02 of a cycle or 0.6 r.p.m. at a speed of 1800 r.p.m. The top speed during the three days was 1804 r.p.m. and the lowest speed was 1795 r.p.m. This is a remarkable testimonial of what can be done with control instruments when really necessary. The utility companies have reached this state of perfection only within the last few years but it would probably be impossible for the independent power systems of the steel industry to approach such accuracy without a large investment in additional power equipment both in boilers and turbo-generators.

Fig. 9 represents one type of maximum loading. While the figure shows the electric load imposed by the works and the violent peaks imposed by the six stands of continuous mill, the chart also represents exactly the flow of steam which the boilers will be required to deliver to the turbo-generators in order that they can carry the load. In these peak loads, the effect of load from each of the six continuous stands is clearly shown.

Notice that each peak is approximately 36 seconds long and that a 30,000 kw peak is applied to the system in 16-seconds of time. While the peak load only represents 185 kw hours of work, the boilers must evaporate 1855 lbs. of additional water during the 36 second interval. The average increase in steam flow over the duration of the peak is at the rate of 185,500 lbs. of steam per hour but the actual maximum rate of flow at the top of the peak requires an increased flow equal to an additional 500,000 lbs. per hour.

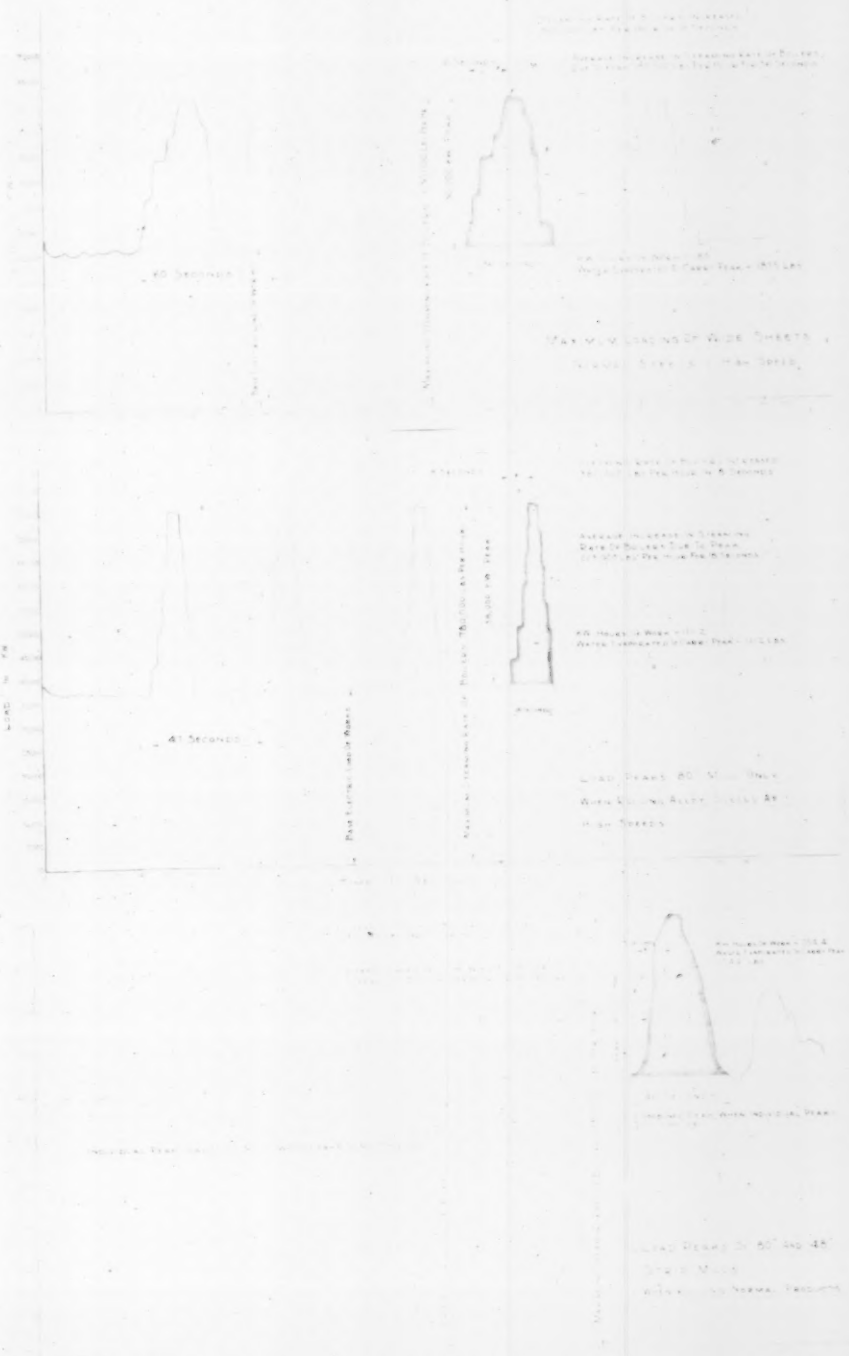
Fig. 10 shows a still more violent change where the boilers will be called upon to increase the flow of steam at the rate of 580,000 lbs. per hour in 8 seconds.

At some later date, a second narrower strip mill may be installed. Time studies showed that it was not practical to stagger the peaks between these two mills without slowing the production of the faster mill to the speed of the slower mill. Peaks on the two mills will, therefore, coincide at times and when this occurs, the load will look something like Fig. 11.

Fig. 11. Notice that the duration of the peak will be about 46 seconds and that it will take approximately 2544 lbs. of additional water flashed into steam during these 46 seconds to supply the peak demand. The boilers will have 15 seconds in which to increase their rate of steam flow 420,000 lbs. per hour.

It would take an exceedingly large battery of boilers to flash 2544 lbs. of additional water into steam in 46 seconds. The loss in pressure from such a cycle would be out of the question. Heat must be supplied from fuel for at least a large part of the evaporation necessary to carry these peaks. When a problem of this kind is recognized during the early design stages, no particular trouble is anticipated in designing a plant to meet the conditions imposed by the service.

The plant will use a combination of purchased utility power and power generated in company owned stations.



This brings up another important popular misconception on control instruments. Salesmen often call on engineers and executives and proudly show speed charts such as the utility charts just shown, or say boiler pressure charts which are almost absolutely uniform through a 24-hour period regardless of the rate of flow of steam from the plant, and many other types of regulation of equal uniformity; boasting that they can give the customer "zero regulation."

There is no such thing as "zero regulation." There must be a change in order that the control instruments can take notice of that change and make the necessary compensating adjustments.

The narrower the limits within which the change is confined, the more sensitive and quicker acting the control instruments must be. Supersensitive quick acting controls induce what is popularly called "hunting" and the nearer the control equipment attempts to approach the so-called "zero regulation," the wilder and "jumpier" the control equipment must be in order to function. The danger of overshooting the necessary control mark is thereby greatly increased.

It is said by utility engineers who have made careful studies of the subject that in the large interconnected utility network now in operation in this country, that a 30,000 kw. load applied in ten seconds will reflect as much as 27,000 kw. into stations 500 miles distant, and further that if this load is suddenly removed after 10 seconds that it will start surges in the system that will take 15 minutes to even out, and return all equipment back to normal operation. It is contended by the author that in setting up instrument control, particularly for independent power systems, that the most essential data to be considered is, through how *wide* a range of variation can the equipment be allowed to swing and still give satisfactory performance, and second, install as little control equipment as will hold the fluctuations of the system within these satisfactory limits of variation.

It was stated earlier in this paper that with the advent of the large continuous mills producing wide flat products, that steel mill power systems were required to absorb violent load fluctuations which were hardly thought possible a few years ago.

A power system must at all times be prepared to handle the *worst* loading that can be placed upon it. A dose of water getting into turbines as a result of overloaded boilers may wreck the turbine unit. Figs. 9, 10 and 11 represent what is considered the worst conditions that will have to be met in order to successfully carry the new U. S. Steel Corporation mill at Irvin.

The startling size and suddenness of the peaks caused considerable anxiety among utility operators as to the effect of such loads on their system. This can be readily understood when the extreme narrow band of speed regulation on utility power systems shown in Fig. 8 is remembered. At length, the utility men were convinced that it was possible to build a station to operate in parallel with their own system and keep peaks of greater magnitude than 10,000 kva. off the utility system.

This can be accomplished in two ways. A station can be built with about double the number of boilers and perhaps twice the requirements in generating capacity so that in the normal load division between parallel operating systems the power station closest to the load would absorb the larger part of the peaks, or a much smaller station can be built that will have proper control instruments that will force the larger part of the peak loads to be carried by the company owned power house close to the point of load application.

The general idea of the control system and its instruments is not particularly complicated.

The turbine must be designed with plenty of overload valves which, during brief periods, will admit large quantities of steam to the unit regardless of economy. The generator must be designed to dissipate the heat caused by these overloads and have pilot excitation that will permit it to pick up the load with the required rapidity. Next, the drop in steam pressure through the superheater tubes and piping at normal and maximum rate of steam flow must be carefully investigated. This may be a 25-lb. pressure loss at normal rates of flow and a 75-lb. loss at maximum rates of flow.

Although every effort will be made to supply fuel to carry the heavy peaks there is a time element in heat absorption which must be made up by flashing water into steam through pressure loss in the boiler. Suppose, therefore, an allowance of 175 lbs. pressure loss during peaks; then, if the turbine required steam at 700 lbs. the boiler would have to carry 950 lbs.

In order to prevent this 950-lb. steam in the boiler drums from reaching the turbine, a pressure-reducing mechanism in the form of a butterfly valve capable of almost instant adjustment is placed between drums and superheater. The opening in this valve is controlled by the steam pressure at the turbine. When the turbine valves open and draw more steam than is being supplied the resulting drop in pressure at once opens the butterfly valve and the large reserve pressure in the boiler drums starts a larger flow of steam at once. The fuel supply to the boilers will respond to the same operating mechanism. The governors on the turbine will have auxiliary remote controls that will be able to increase or decrease the load carried by the unit.

In the substation receiving utility current, the maximum relay will normally be open and will close only when an inrush of current exceeds some predetermined maximum while the minimum relay will normally remain closed and open only when the incoming utility current drops below the predetermined minimum.

Should the maximum relay close due to a heavy increase in current supplied to meet a large peak, a timing mechanism starts increasing the load carried by the turbo-generator in 5,000-kw. steps at say two-second intervals until the incoming utility current is restored to its predetermined rate of flow. Should the minimum relay open because of loss of load, the reverse operation takes place and load on the turbine is relieved, in the reverse action of the manner in which it is increased.

The base load carried by the turbine is determined first by the minimum limits set for the turbine control and second by the number of amperes at which the minimum relay is set to open.

It all sounds simple but you may be assured that when all the functions of superheat control, feed water control, forced- and induced-draft control, auxiliary fuel control and all the rest of the various controls are tied into this system, it will take a well-qualified group of specialists to coördinate the various functions of all the instruments.

Automatic control instruments far exceed any human control. They will not divert their attention from their job. If properly designed, they should not require excess servicing to keep them in order. They can sense and compensate for changes so small that they would hardly be noticeable to the human and they act much faster than a human. If, therefore, a job of careful regulation is required, it is safer to trust it to control instruments than to the average human.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# Pendulum Method of Measuring Hardness

By S. R. WILLIAMS
Professor of Physics, Amherst College

THE HERBERT PENDULUM HARDNESS TESTER

The most ingenious and at the same time the most fascinating of instruments for measuring the hardness of materials is the one devised by E. G. Herbert[1]. It consists of an inverted, U-shaped mass as shown in Fig. 191. When used in testing the hardness of materials it

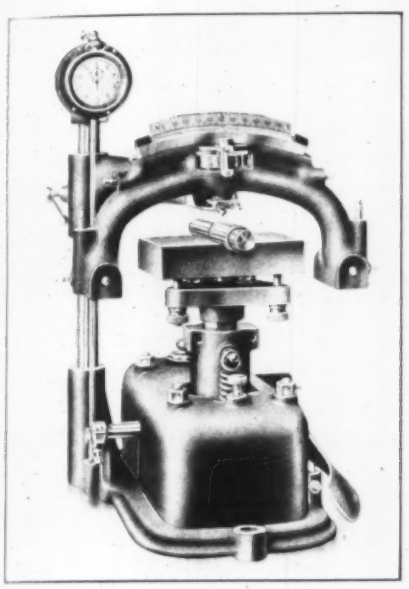

Fig. 191. The Herbert Pendulum Hardness Tester with operating stand.

rests on a hard, steel ball 1 mm. in diameter, or on a ball-shaped diamond of the same diameter. For soft materials a 3-mm. steel ball may be used. Ball-pointed diamonds of 1 mm. diameter can be furnished for testing hardness ranging as high as that of sapphire. See Fig. 192 (a) and (b).

The Herbert pendulum really constitutes an inverted compound pendulum with a moving point of support, in which the center of mass of the pendulum lies 0.4 mm. above the point of support when the center of the bubble in the level tube lies at the "50" point on the 0-100 scale. (This level scale may be seen at the top of the instrument in Fig. 191.) In order to understand

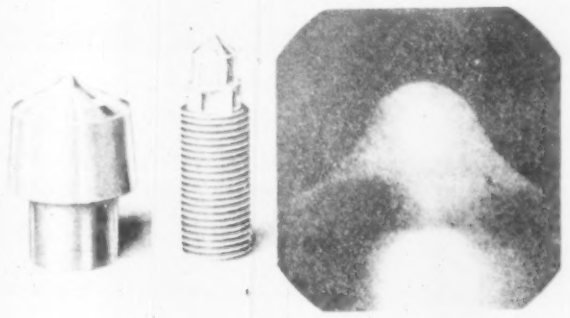

Fig. 192. Spherical-faced diamonds. The 1-mm. diamonds used in the pendulum are shown in (a), full size. In (b) is shown the 1-mm. diamond, magnified 15 times.

[1] E. G. Herbert, Some Recent Developments in Hardness Testing. *The Engineer*, Vol. 135, 1923, pages 686-687.
Also in *Machinery* (London), Vol. 22, 1923, page 76.
Anon. Work Hardening of Metals and the Herbert Tester. *The Engineer* (London), Vol. 137, March 7, 1924, pages 248-251.

the behavior of this peculiar form of pendulum it will be necessary to explain two fairly common types of pendulums.

1. *The Simple Pendulum.* Foucault[2] suspended from the dome of the Panthéon in Paris a large iron ball by means of a steel wire 67 meters long. The mass of the ball was 28kg. From a practical point of view the Foucault pendulum may be considered a simple one. In the ideal simple pendulum the mass of 28kg. would have to be concentrated in a point at the lower end of the wire and be supported by a weightless, inextensible wire 67 meters long. For such an ideal pendulum the length of a complete period is given by the equation:

$$T = 2\pi\sqrt{(l/g)},$$

where $l$ is the distance in centimeters between the point of support, S, and the point where the mass, $m$, is concentrated. See Fig. 193 (a). $g$ is the acceleration due

Fig. 193. A simple and a compound pendulum compared. They are supposed to have the same period.

to gravity and has a value of about 980.2 cm sec$^{-2}$ in Lat. 42° N. From this equation it will be seen that the greater the length $l$ the longer will be the period of vibration. Rigorously, a simple pendulum cannot be physically realized.

2. *The Compound Pendulum.* In order to make sure that we know exactly the conditions under which we are operating, use is made of the compound, or physical pendulum as it is sometimes called. See Fig. 193 (b). The compound pendulum is composed of an infinite number of simple pendulums as indicated by the masses $a$, $b$, $c$, etc., hence its name, compound pendulum. From the equation for the period of a simple pendulum, which has just been given, the mass $a$ tries to vibrate with a shorter period than the mass $b$ or mass $d$ from the common support $S$. If the compound pendulum remains as a unit it must swing as a whole and with a common period for all parts. It will swing as though its entire mass were concentrated at a definite point $O$ in the pendulum whose distance from the knife-edge $S$ is equal to what is known as the equivalent length of the simple pendulum. If a simple pendulum is hung up beside the compound pendulum and both have the same period, then the length

[2] S. R. Williams. A Short Foucault's Pendulum. *Popular Astronomy*, Vol. 40, 1932, pages 1-8.

of the simple pendulum will be the equivalent of the distance from $S$ to $O$ in the compound pendulum and $S$-$O$ is called the equivalent length of the simple pendulum. The point $O$ is called the center of oscillation, but must not be confused with the center of mass. If the entire mass of the compound pendulum were concentrated at $O$ it would still continue to oscillate with the same period. The point $O$ corresponds to the so called point of percussion, that point in the baseball bat with which the batter wishes to hit the ball without stinging his hands.

The pendulums thus described were supposed to be supported on ideal knife-edges. Herbert's pendulum has been called an inverted compound pendulum, because its center of mass lies above the point of support. If one should invert the compound pendulum shown in (b), Fig. 193, it would be evident at once that it would not oscillate in an inverted position, because the moment the center of mass passed either to the right or to the left of the vertical line passing through the knife edges the pendulum would keep on going and fall over.

The unique and ingenious feature about Herbert's compound pendulum is that instead of oscillating over a knife edge its center of gravity lies above a point on a spherical surface whose radius is 0.5mm. On this curved surface the pendulum rolls as its swings back and forth, with the result that the point of support is not fixed as in the case of the knife edge.

In thus rolling on a spherical surface, the point of support moves to the right, if the pendulum is tipped to the right, thus throwing the center of mass to the left of the vertical line through the point of support which produces a torque causing the pendulum to swing back again toward its equilibrium point. Due to the large inertia of the heavy pendulum the latter passes through the position of equilibrium to a deflection toward the left where the center of mass now lies to the right of the vertical line through the point of support; and so the vibrations continue until the energy imparted to the pendulum to start it swinging is transformed into other forms produced by friction and the cold-working of the metal under the ball.

One may visualize this more easily by considering the irregularly shaped pendulum of Herbert's as a large steel ball from the upper side of which a sufficient amount of metal has been removed to lower the center of mass from the center of the original sphere $C$, Fig. 194, to the point $m$, a distance equal to 1/10 of the diameter of the sphere. When the sphere is in equilibrium the point $m$ lies vertically above the point of contact $b$, Fig. 194. When the ball rolls to the right so that $v$ becomes the point of contact on the surface $A$-$B$, the center of mass $m$ will then lie to the left of the vertical line $cv$. This produces a torque equal to $mgL$ tending to roll the ball back to its position of equilibrium, where $b$ is in contact. The length $L$ is the distance between $m$ and the vertical line $cv$ when $v$ contacts $A$-$B$. It is the arm's length of the lever at which the mass of the sphere is working. As the ball rolls back to its position of equilibrium, the rotational inertia of the same carries the ball through the position of equilibrium until $m$ lies to the right of the normal to $A$-$B$ at the point of contact. Thus oscillations are set up in which the period of oscillation will be smaller the greater the distance at which the point $m$ lies to one side or the other of the line rising vertically through the point of contact.

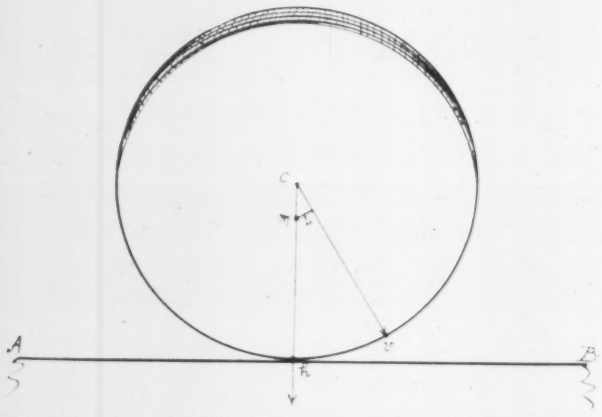


Fig. 194. A steel ball has a portion of its top ground away, so that its center of mass is lowered from C to $m$, a distance one-tenth of its diameter. As the ball rolls to the right, the center of mass $m$ will be a distance $L$ to the left of the line of support when the point $v$ on the ball contacts the surface $A$-$B$. This produces a torque, acting to roll the ball back to neutral position at $b$.

Thus far in the discussion we have assumed that the ball rolls on a surface $A$-$B$ so hard that no indentation occurs. Ideally $A$-$B$ should be infinitely hard for calibrating the period of the pendulum. Suppose, however, that as the ball rolls along on the surface $A$-$B$ it leaves a permanent rut in the surface. From the use of the microcharacter and other permanent-deformation methods we know that for a given load the permanent trace will be wider or deeper the softer the material over which the indenter moves. The same holds true for the trace left by the Herbert tester as it rolls a short distance along the surface of a deformable substance. Furthermore, as the ball rolls, it pushes up a wave of the material in front of the ball, as shown in an exaggerated form in Fig. 195. In this picture the rolling ball has moved forward until $v$ is vertically below the center of the ball.

Benedicks and Christiansen[1] established the fact that "the motion of the pendulum ball, on the swinging of the instrument, is a purely rolling (not sliding) one." Inasmuch as the ball rolls along its course pushing the material of $A$-$B$ ahead of it, the point of suspension of the ball is not $v$ as in Fig. 195, but some undetermined point $w$ still farther to the right. The center of mass $m$ now lies a distance $L' - mb$ to the left of the vertical line through $w$ and because $L' - mb$ is greater

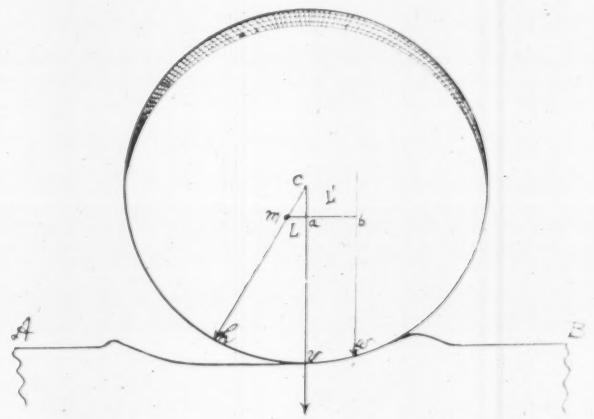


Fig. 195. When the ball rolls along the surface $A$-$B$ of a deformable substance, the average point of contact lies somewhere in the region of $w$. This makes the restoring torque greater for soft metals than for hard.

[1] C. Benedicks & V. Christiansen, Investigations on the Herbert Pendulum Hardness Tester, *Journal Iron and Steel Institute*, Vol. 1, 1924, pages 219-238; discussion, pages 239-248.

the *l.—ma* in Fig. 195, we have the paradox that the softer the material, the smaller will be the period of oscillation because the restoring torque is greater for soft than for hard materials.

In Fig. 191 the Herbert pendulum was shown with its operating stand. When not supported on the steel ball or the spherical end of the diamond, the pendulum rests on a three point support on the horizontal arm of the operating stand.

The steel lever at the right of the base is raised as high as it will go, which allows the table on which the specimen rests to settle to its lowest point and to be locked there. A downward push of the lever releases the table and, by reason of an oil dashpot for restraining the motion, the table slowly rises a distance of about $\frac{1}{4}$". In this movement of the table the specimen is raised until it intercepts the steel ball on the pendulum and the latter is then free to swing back and forth. A small flat spring under one side of the pendulum gives it sufficient energy for the proper amplitude of swing. Further operation of the handle downward sets the stop watch in motion, stops it, or sets it back to zero. Before each reading the lever is lifted to its highest point which returns the table to its lowest point and leaves the pendulum resting on its three point support. The horizontal arm on which the pendulum rests when not in use may be moved up and down to allow specimens 6" in depth to be measured. It should be placed for each specimen so that the steel ball of the pendulum is about 1 16" above the surface to be tested.

The Herbert pendulum may be used on irregularly shaped objects when these are held in a universal ball vise. See Fig. 196. When thus used without the advantage of the operating stand shown in Fig. 191 the instrument becomes a portable hardness tester. When the specimen is clamped in the vise as shown, the pendulum, held in both hands, is gently lowered onto the surface to be tested, with the indenter finally carrying the entire load of the pendulum and the latter free to swing when touched by a light feather. The operator must be careful to keep the bubble at the desired mark on the scale when the pendulum is thus used.

Fig. 196 The Herbert Pendulum Hardness Tester used on a specimen when clamped in a universal ball vise.

Herbert's pendulum hardness tester may be used in four different ways:

*1. The Time Test.* In the first method the pendulum is rested on the article to be tested with the bubble vertically over the supporting diamond or steel ball. The instrument is then set swinging through a small range by lightly touching it with a feather or by means of the small spring already described. The periodic time of the swing is taken as a measure of the hardness of the material under test. In order to increase the accuracy of time measurements, the interval which is measured with a stop-watch is the time it takes the pendulum to make five complete vibrations: this period in seconds is known as the "time hardness figure."

When the pendulum has its center of gravity 0.1 mm below the center of support, its half period when set to rock on a surface of extreme hardness should be 10 seconds, so that it will take 100 seconds for the pendulum to complete five full or ten half periods of vibration. The number 100, therefore, stands for the "time hardness number" of maximum hardness. Glass is the best available surface on which to standardize the pendulum. The glass designated as "C" by the Corning Glass Works is the hardest of the glasses which they produce.

The pendulum is sent out from the factory in proper adjustment, ready to use, but it should always have its adjustments verified. This is easily done by rocking the pendulum on a piece of hard plate glass and noting by means of the stop watch whether the period is greater than or less than ten seconds. A change in the length of the pendulum and consequently in the period is easily made by means of the circular mass which moves up and down on the center of the pendulum by means of a fine screw. When the half period is equal to 10 seconds and the horizontal screws have been adjusted so that the pendulum swings equally about the figure 50 on the curved scale, the instrument is ready for use.

Table I gives some of the typical time hardness numbers:

TABLE I

| Materials | Time Hardness Numbers | Scale Hardness Numbers |
|---|---|---|
| Glass | 100 | 97 |
| "Very Hard" Carbon Steel | 75 | 93 |
| "Hard" Carbon Steel | 63 | 88 |
| Tempered High-speed Steel | 52 | 77 |
| Annealed High-speed Steel | 26 | 54 |
| Annealed Carbon Steel | 22 | 41 |
| Rolled Brass | 13 | 13 |
| Cast Brass (soft) | 11 | 4 |
| Lead | 3 | 0 |

*2. The Scale Test.* A second kind of test which can be made with the Herbert pendulum is the so-called scale test, which measures hardness as judged by resistance to deformation by rolling. Great care must be used in making this test. Particular attention must be paid to leveling the specimen, preparing the specimen and balancing the pendulum. The pendulum is held in both hands and lowered gently onto the surface of the test piece. Its initial position is a tilted one in which the zero mark divides the bubble. When finally placed in this position, the pendulum is released without impetus and the position of the center of the bubble is noted at the end of the first swing which the pendulum makes. This reading is the "scale hardness number". In order to eliminate errors due to faulty leveling of the specimen the test should be repeated with the pendulum placed at a new point and tilted to the left with the bubble at the "100" mark. If the specimen is uniform and the pendulum is properly adjusted, the bubble

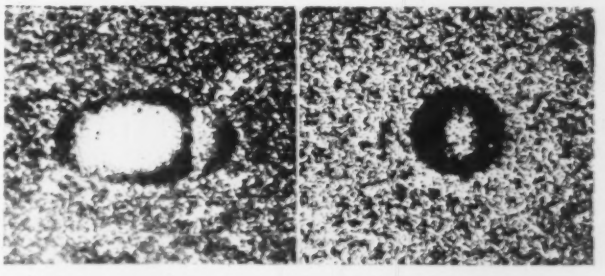

Fig. 197. Time and scale indentations of the Herbert Pendulum Hardness Tester. (Magnified)

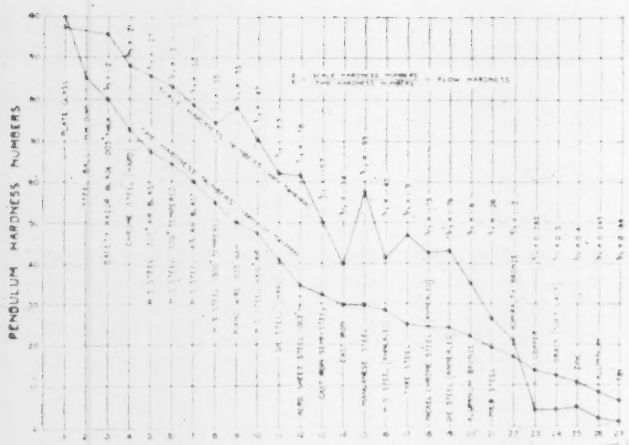


**Fig. 198. Time and scale hardness numbers of various solids as measured by the Herbert Pendulum Hardness Tester.**

should pass over the same number of divisions in the opposite direction. When the pendulum is placed on the specimen the weight of the pendulum causes the ball to make a spherical imprint, but on releasing the pendulum this indentation is rolled out into an elongated form. Fig. 197 (b) shows how the elongation looks when a scale test is made. Fig. 197 (a) is a photograph of the imprint due to a time test. Inasmuch as the pendulum swings through a small arc the imprint is only slightly elongated. When the pendulum is released in the scale test, a deformation by rolling is produced and if the resistance to deformation is large the ball rolls out a shallow imprint and only a small amount of the metal is displaced. As this requires only a small expenditure of the energy of the pendulum, the pendulum will make a wide swing, whereas if the specimen has low resistance a large wave of metal is pushed in front of the ball and this exhausts the energy of the pendulum before it has traveled much of the distance in its vibration. Thus in the table just given it will be seen that the pendulum swings to 97 on glass but for lead it does not swing at all.

Herbert tested twenty-seven metals for both time and scale hardness numbers which are recorded in Fig. 198. From Table I and from Fig. 198 it may be seen that there is no simple relation between the two tests. For instance, manganese steel shows an unusual departure from the other metals in its scale hardness number. As

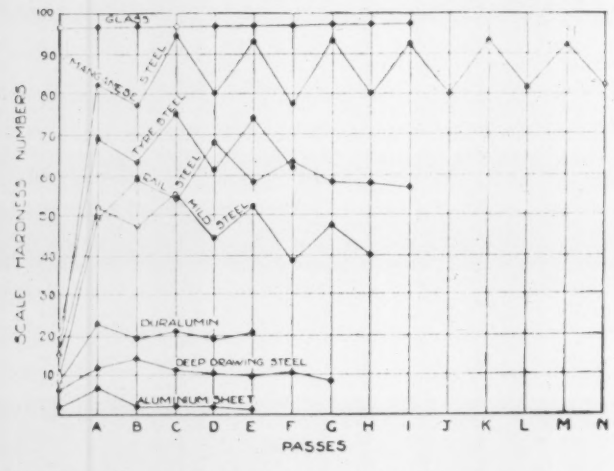


**Fig. 199. The work hardening capacity of various substances as measured with the Herbert Pendulum Hardness Tester.**

***(Courtesy of E. G. Herbert.)***

will be observed from Fig. 198 Herbert calls the ratio

$$\frac{S}{T} = \frac{\text{Scale Hardness Numbers}}{\text{Time Hardness Numbers}} = \text{Flow Hardness}$$

The numbers, 0 to 27, used as abscissas in Fig. 198 are simply the various materials arranged in order of decreasing indentation hardness. The pendulum time test (time hardness numbers), like the Brinell test, measures resistance to indentation. It is an "indentation hardness" which is measured. By means of formulas the pendulum hardness numbers may be converted into Brinell hardness numbers.

*3. Time Work-hardening Test.* A third use to which the Herbert pendulum tester may be put is the time work-hardening test. This test measures the hardness actually induced in a metal by cold working. The procedure is as follows: (1) take a time test as has been described above. (2) Without removing the pendulum from its position, tilt it to 0, then to 100, and finally back to 50. The ball has now rolled along the surface of its elongated imprint two times and the surface of the imprint has hereby been work hardened. (3) After about five vibrations take another time test and the time in seconds for ten single swings is the "induced time hardness number." This process may be continued for 4, 6, 8 or more passes of the ball over the elongated imprint in which, in general, it will be found that the hardness increases up to a certain point and then decreases. This test measures the resistance of metals to deformation whether by tools or by severe abrasion and gives us some knowledge of how metals will behave when being machined, and how they will stand up to abrasive processes such as one gets on the surface of a plow share.

The values in Table II show to what extent the hardness has been increased in various steels due to two passes of the ball over the elongated imprint.

TABLE II

| *Material* | *Original Hardness* | *Induced Hardness* |
|---|---|---|
| Hard tool steel | 67 | 80 |
| Manganese steel | 23 | 53 |
| Stainless steel | 27.5 | 41 |
| Mild steel | 21 | 30 |
| Deep drawn steel | 12 | 18.6 |

Instead of actually rolling, the steel ball may slip and, therefore, no elongated imprint will be produced. If for any material this slipping occurs, an etched steel ball should be used and on soft metals it may be necessary to use a 3 mm. ball in place of the standard 1 mm. ball.

*4. Scale Work-Hardening Test.* The fourth way in which the Herbert pendulum may be used is in measuring the capacity of metals to become harder as a result of being cold worked. All metals possess in greater or less degree the property of becoming harder when they are cold-worked by hammering, by abrasion, by rolling, by polishing and by other processes. It is of considerable interest to those who work with metals to have some knowledge of the work-hardening capacity of these substances. Careful preparation of the surface of the test specimen should always be made.

The procedure for this test follows the scale hardness test, and is as follows: (1) The pendulum is held by both hands with the bubble at 0 and then carefully lowered in this tilted position onto the surface of the specimen. The reading of the center of the bubble at the end of the first swing is the original scale hardness. (2) Next, work-harden the specimen by tilting the pendulum until the middle of the bubble is at the 100 mark. (3) Release the pendulum from the position of 100 and again note the position of the center of the bubble at the end of the reverse swing, taking as a reading the actu

number of divisions over which the bubble has passed. Thus if the center of the bubble lies at 40 the reading will be 60 for the scale hardness after one pass of the indenting ball. (4) Work-harden the specimen further by shifting the pendulum back to 0. Release it from this point (again without impetus) and note the scale reading which will be the scale hardness number produced by two passes of the ball. Secure in this fashion five readings and subtract the first (original scale hardness) from the average of the next four (average induced scale hardness). The difference is the "work-hardening capacity" of the metal, *i. e.*, the average increase of hardness due to rolling one to four times. Typical scale work-hardening numbers are given in Table III, while

TABLE III

| *Material* | 1st | 2nd | 3rd | 4th | 5th | *Av. of last four* | *Work-hardening capacity* |
|---|---|---|---|---|---|---|---|
| Hard tool steel | 83 | 92 | 95 | 94 | 96 | 94.3 | 11.3 |
| Manganese steel | 14 | 83 | 78 | 95 | 80 | 84 | 70 |
| Stainless steel | 18 | 71 | 66 | 79 | 76 | 73 | 55 |
| Mild steel | 15 | 52 | 48 | 55 | 45 | 50 | 35 |

in Fig. 199 are plotted the various scale hardness numbers which follow the various passes made by the indentation ball along the elongated imprint. Here again care must be taken that in making the passes the ball does not slip but rolls. If slip occurs, either an etched or a large ball should be used.

Fig. 199 brings out a number of interesting facts. Glass shows no work hardening capacity. Manganese steel jumps from an initial scale reading of 15 to a scale reading of 95 after 3 passes. Cold working causes manganese to change from a hardness equivalent to a mild steel to that of a hard tool steel. Once again manganese demonstrates its peculiar properties. The zig zag effect in the scale readings for the successive readings of the bubble in the pendulum is due to the path rolled out by the ball being deeper at one end. The ball rolls up and down a small inclined plane.

*Pendulum Hardness Numbers with Varying Temperatures.* Under the painstaking care of Mr. Herbert, his pendulum tester has been developed for use in testing the hardness of metals at both high and low temperatures. There are two tests in particular to which attention should be drawn: (1) Time Tests on Hot Metals; (2) Temperature Work-Hardening Tests.

(1) In order to carry out the first test it must be so arranged that the specimen can be kept at a known temperature while the time hardness number is determined. In Fig. 200 is shown an electric furnace in which the specimen may be heated and to which is attached a pyrometer for measuring the temperature. The furnace is a resistance heater built around a leveling table on which the specimen is mounted. The spherical-face diamond should replace the steel ball in making the tests for "hot-hardness." Only the diamond can withstand the combination of high temperature and intense hardness. With the diamond replacing the steel ball, all tests may be carried out on hot metals as one would carry them out for specimens at room temperature. Throughout the measurements the specimen remains in the furnace. In order to assure oneself that the temperature of the surface being tested is the same as that given by the pyrometer it is desirable to imbed a thermocouple junction in a hole drilled in the edge of the specimen. The "hot hardness" test is one of the most important uses to which the Herbert pendulum may be put. In cutting operations with machine tools, heat is generated and the value of a cutting tool depends on its hardness when hot. This can be determined by the process just described. Fig. 201 shows how a special steel ("Rapidor") maintains its hardness as the temperature increases. This high-speed saw blade steel contains 18% tungsten and is compared with five other steel saw blades containing 2% tungsten. It is readily seen from the curves why "Rapidor" has its great capacity for rapid cutting at high speeds.

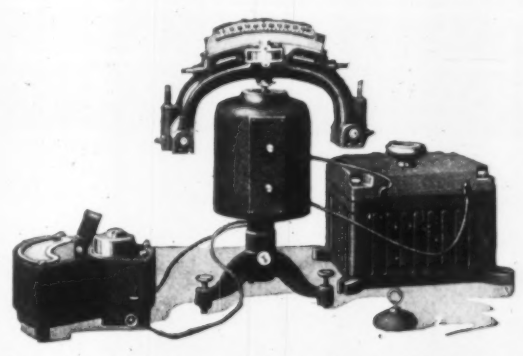

Fig. 200. Electric furnace and pyrometer for hot hardness and temperature work hardening tests.

(2) For carrying out the work-hardening tests at high temperatures, considerable attention must be paid to the preparation of the surface of the specimens. It should be prepared by wet grinding and hand polishing to avoid the use of cutting tools which might cause local work-hardening. With the added precaution of a junction of a thermocouple in a hole drilled in the edge of the specimen, the work-hardening tests are carried out

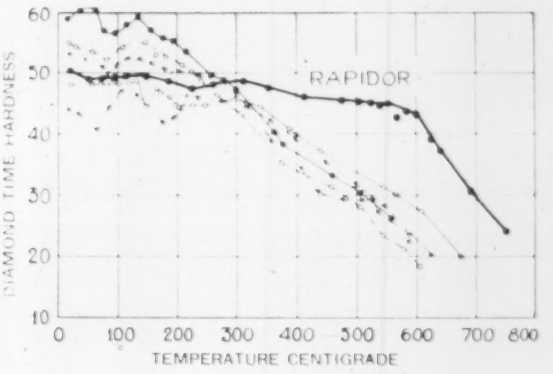


Fig. 201. Hot hardness curves of "Rapidor" and other saw blades.

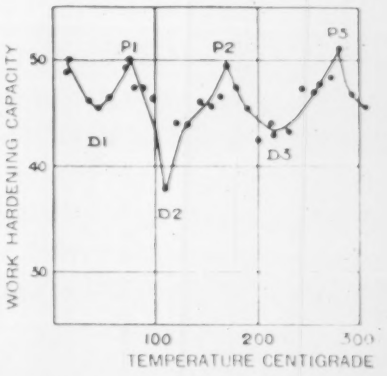


Fig. 202. Temperature work-hardening curves of Vickers' test bar steel.

as for those at room temperature. Fig. 202 shows the cycles through which Vickers' test bar steel goes as its work hardening capacity changes with increasing temperature. In developing all of these tests at high temperatures Herbert has advanced as perhaps no one else has done our knowledge of the art and science of hardness testing.